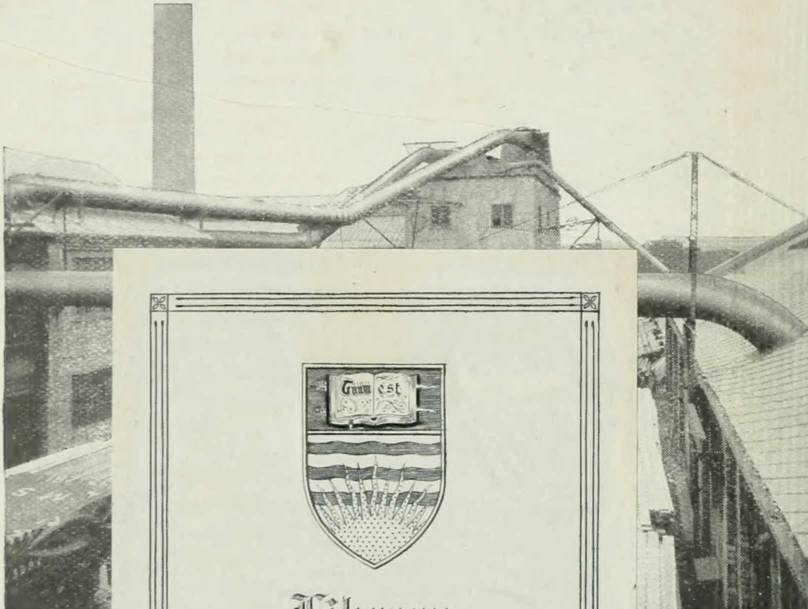
MANUAL OF FOREST ENGINEER[...]CTION

J. F. STEWART



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MANUAL OF FOREST ENGINEERING AND EXTRACTION

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Manual of Forest Engineering & Extraction

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PREFACE

In lecturing on Forest Engineering to the forestry students of one of the Universities, I found them handicapped by the want of a simple textbook on the subject. I was asked to write one, and this work is the result.

While primarily written for forestry students, it is hoped and believed that it will be equally useful to all engaged in timber exploitation in any part of the world.

Some of the matter may seem to be outside the scope of the Forest Engineer. For example, Chapter II, while including the inspection and measuring of timber, deals principally with travelling in wild country, camping, protection against wild animals, malaria, snake-bite, and so on. If this is criticised, I can only reply that as a Forest Engineer of long experience in every climate, I have not gone outside that experience in writing this or any other chapter in the book. After all, before one can plan to take away timber from any unexplored or little known country, one has to make sure the timber is there, and find out what the country is like for working, and one must just go and see. I hope the results of my own experiences in such circumstances may be useful to those of my readers who may have to do the going and seeing for the first time, and may add somewhat to their efficiency and comfort.

This book has been written purely from the practical and not the theoretical standpoint, and as it is intended for those who have had no special training in engineering, technical terms and phrases have as far as possible been avoided.

The special object has been to show how much of the construction work necessary in logging and other forest operations can be carried out with the unskilled labour which is all that is usually available, and with the materials afforded by the forest itself. There is no pretension of dealing with heavy permanent structures of a nature requiring the supervision of the skilled civil engineer or builder.

My very grateful thanks are due to the various Governments, firms and individuals who have interested themselves in my work, and who have supplied me with so much of the material which illustrates the book, and to Nobel Industries, Ltd., for having given the authoritative method of destroying dynamite.

In particular, I would wish to thank Professor Stebbing for his encouragement, without which I would probably not have carried out the work, for his valued suggestions, and for the trouble he has taken with the proofs.

I would also wish to avail myself of this opportunity of urging all engaged in Forestry or Timber Exploitation throughout the Empire to join and help forward the Empire Forestry Association, whose good offices on many occasions I have great pleasure in acknowledging.

J. F. STEWART.

TRAQUAIR,
ST. ANDREWS.
July, 1927.

INTRODUCTION

I HAVE been invited to write a brief introduction to this small work on Forest Engineering and extraction. The Author is a practical exponent of the subject which he deals with and, as stated in his Preface, the book is written from the purely practical point of view. This in my opinion, an opinion which will, I think, be shared by many Forest Officers and those engaged in timber exploitation, renders Mr. Stewart's treatment of his subject all the more valuable. In common with many of my confrères, I often felt the want during my service in India, of just such a reference work as the author gives us here. The Forest Staff in India now includes the Forest Engineer, but many of the Forest Services under the Colonial Office are in much the same period of progress as had been attained in India twenty to thirty years ago. In other words, the district Forest Officer had to be his own Engineer for all work which did not fall within the purview of the Public Works Engineer; and there was little work of the latter type within the forests proper.

For the student of Forest Engineering we have, so far, had no simple text book in the English language written by a man whose career has been that of a practical Forest Engineer acquainted with different conditions within the Empire. I have little doubt that Mr. Stewart's work will prove of great assistance to all who aim at making themselves efficient to fill a post either in timber exploitation or as Forest Officer—one of the finest careers attainable to young men who wish to pass a varied and most interesting life in the open air.

The Author and his Publisher may be congratulated on the general get up of this book. The numerous illustrations elucidate the text in a clear fashion. Mr. Stewart's work should prove a boon to many a young Forest Officer with a troublesome problem to solve and translate into a practical result.

E. P. STEBBING.

University of Edinburgh,
August 27, 1927.

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MANUAL OF FOREST ENGINEERING & EXTRACTION

CHAPTER I

OBJECTS AND METHODS

Introductory—Utilisation of forest products—Organisation—Choice of power.

Owing to the rapid denudation of the forests of the principal timber producing countries, and the possibility of a timber famine at no very distant date, Forestry has assumed an importance throughout the world to which it has never before attained. The profession of Forestry has attained equal importance, and it is not sufficient for the Forest Officer to be trained only in the cultivation of trees, their diseases and peculiarities and so on. Trees, after all, are not grown merely to be ornamental, although they are naturally so, but to supply various products to the needy markets of the world. The chief of these products are logs for sawing into lumber, pulp-wood for paper-making, pit-wood, wood for distillation and the extraction of some valuable substance, such as the quebracho of South America, resin, charcoal and others.

Although the Forest Officer cannot be expected to have a knowledge of the further processes, it is necessary that he should have some training in rough and ready engineering methods to enable him to plan and construct the means of bringing the tree to the manufacturer, and particularly to carry out such construction with the materials the forest itself provides, and with the more or less unskilled labour which is usually ready to hand.

He cannot be an expert in everything, and when for example big steel or masonry bridges must be built to carry heavy traffic, it is time to call in the civil engineer.

In a very long experience in every climate in the world, the writer has probably had to cope at one time or another with every forest engineering proposition which is likely to confront the Forest Officer working in virgin country, and he has not in the following pages gone outside his own experience. With the help of this Manual and his own judgment, therefore, it is hoped that the Forest Officer will be able without calling in outside help to carry out any work that is here described. If he is able to do this, it is unlikely that any requirement of forest extraction will find him at a loss.

In regard to less bulky products, such as resin, all the Forest Officer will be called on to do will be to provide roads and bridges for the collectors and their carts and other small vehicles. At the other end he has to devise and construct the means of transporting the heaviest logs from the stump to the mill or market. The means may be only slow dragging by men or oxen, or it may be the most powerful and rapid of all, the high lead system, and in between these extremes there are many various methods with which he should be conversant, one or more of which may be called for by peculiar local conditions. In correctly adapting any particular method to some special condition may lie the profit of a timber operation. It is quite impossible in a written work to lay down dogmatically the method which should be adopted in any particular case, and the Forest Officer must be able to judge this for himself after going over the ground. All the Manual can do is to give suggestions and show how to carry them out.

The organisation of any extensive timber operation will be governed largely by climatic and local conditions. In an operation in northern latitudes it is usual for the operator to provide camps, food, cooks and other servants, means of transport for the lumbermen, medical attention and so on. In other countries, especially with coloured labour, the natives look after themselves, house themselves and feed themselves, and the employer has no responsibility beyond paying them for their work. In the latter case also, the whole of the logging is often carried out by contractors, and if this is done, it is possibly as well to work according to local custom.

The writer, however, has never done this, but has always found it more profitable for himself and more satisfactory for all parties to provide housing and food for all his coloured labour as well as white, and to exercise some supervision and insist on a certain amount of order and discipline even out of working hours. This is of course in an undeveloped country where there are few or no habitations on the spot. The subject of camps with accompanying sanitation and hygiene is dealt with in the next chapter.

On the matter of payment of labour the writer has always preferred, instead of contracting, to pay a bonus on the work done, and has found it satisfactory. It is easy to decide what a good day's work on any particular job is, and to think of it as so many units, and then for every so many units satisfactorily done above this, to pay an agreed bonus. But the work must be satisfactory. The writer, too, in every country he has worked in where he has been able to introduce this system, has paid the bonus to the gang, not to the individual. He has always believed in carrying out the whole of his work not directly with the individual native labourer, but through a local native whom he has carefully chosen and put in charge of a whole gang. He has always been able to get more, better, and cheaper work on this plan than otherwise, and with more freedom from worry, while his labour was more contented. If any member of the gang is a slacker and not doing his share, his companions will either see that he does or will clear him out.

For the benefit of a Forest Officer newly appointed from this country to a part of the world where he has to work with uncivilised or semi-civilised natives, perhaps a few hints as to managing labour may not be out of place. The writer has been particularly successful with his coloured labour and has handled almost every possible variety of it. He has found it profitable to provide comfortable housing and surroundings, good food, and comforts of any reasonable kind, and although he has worked with tribes whom he has heard universally condemned as useless, he has always found it possible to work on a sense of pride, which may be latent, but which is there. No fault or shortcoming should ever be overlooked, but should meet with just punishment immediately. On the other hand a promised reward for good work should never be withheld or quibbled about, but should be paid promptly. The native as a rule does not understand benevolence, but he does understand justice and a square deal, and no fit of temper should ever intervene to keep this from him. Incidentally it may be mentioned that even the most stupid looking native is likely to be the shrewdest possible judge of character. He will have correctly summed up his white employer in the first few minutes of their contact, and will know from the beginning what to expect from him or how far he can presume with him.

With regard to the kind of power to be used in any timber operation, this must depend on the nature of the operation and the local conditions as well as the kind of labour available.

Logging for pit-wood, even when it comes to handling individual logs of very great weight may be quite profitably undertaken from start to finish without any other power than man, if the country is suitable. Much timber only grows on the lower slopes of valleys, on river banks, or in the limited circle round lakes. In the very extensive operations for logging and sawing pit-wood illustrated in Figs. 3 and 4, the whole of the transportation was done by man power alone. The timber all grew on steep hillsides, on both sides either of a good-sized river or of streams carrying a considerable volume of water leading into the river. Tracks at intervals were cut through the woods for main drag roads from the stream to the top of the hill where the timber thinned away to scrub. Similar tracks were cut from these branching upwards and outwards till they met corresponding tracks from the next main roads. All roads had therefore a down grade. Skids, which can be seen in Fig. 4, were placed across the track and the logs slid down to the water.

In this operation it would not have been a paying proposition to bring in either draught animals or mechanical power

FIG. 1. SPRUCE AND FIR FOREST FOR PULPWOOD: LABRADOR.

FIG. 2. SPRUCE AND FIR FOREST FOR PITWOOD: NEWFOUNDLAND.

[To face p. 4.

Fig. 3. Pitwood Logging: Newfoundland.

[To face p. 5.

of any kind. The lumbermen were quicker, handier, and cheaper than anything else could have been. The situation of course was ideal, and the logs after reaching the streams were driven down to salt water, where they were sawn up into pit-wood and stacked ready for shipment as shown in Fig. 102.

In regard to power for driving plant also, even although there is abundant firewood to stoke boilers and work by steam, it may not always be profitable or feasible to get in a heavy steam engine and boiler. For example in the pit-wood operation just mentioned, it was found to be cheapest to saw up the pit-wood with a saw such as the "Forestry" sawbench shown in Fig. 5, which also, it may be mentioned, did a good deal of useful general work. Conditions were not very convenient for a steam engine and boiler, while the refuse from sawing the logs into pit-wood was quite insufficient to keep up the necessary continuous head of steam, and to obtain this it would have been necessary to keep a gang of men doing nothing but cutting and transporting firewood. Therefore a small paraffin engine (see Fig. 6) was installed and gave the utmost satisfaction. This engine starts up cold with the fuel oil on which it runs. It has the advantage over steam that when it is not in actual use, it can be stopped and is costing nothing. The fuel is not bulky like wood or coal, and was easily brought into the mouth of the river with the ordinary supplies. The attendant, who also worked one of the saws, was a fisherman who had never seen any kind of engine before, but who had probably a natural bent for mechanics, and who took much pride in his engine and kept it in good order. It gave the utmost satisfaction at a much lower cost than would have been the case with steam in this particular operation. It never showed the slightest signs of deterioration, and it never had or required at any time the services of a skilled mechanic.

It is, therefore, worth while considering whether to run a small plant by such an engine as this or by steam, even if wood fuel is handy. In this case there was no question which was better and cheaper.

While mechanical plant and steam are advisable or necessary in most timber exploitation this is not always the case. The pit-wood operation above described employed about one hundred and fifty men, felling, driving, sawing, and stacking.

FIG. 4. SKIDDING LOGS BY HAND: NEW-FOUNDLAND.

[To face p. 6.

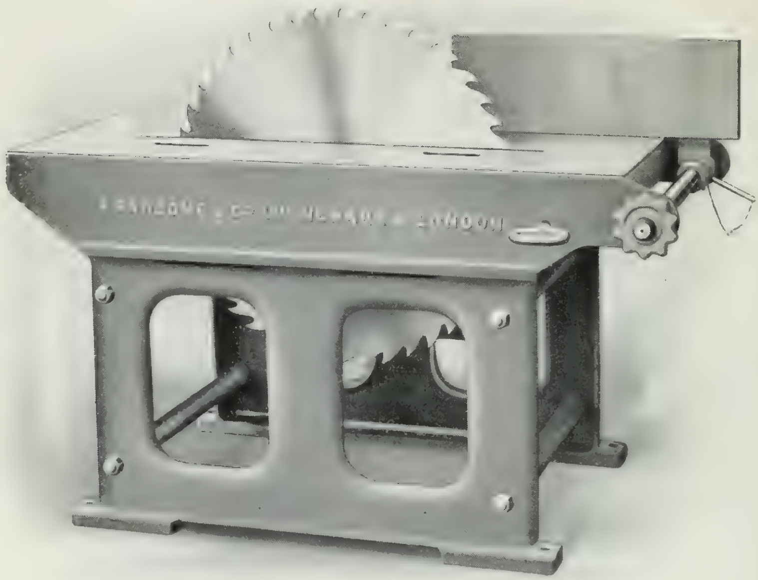

FIG. 5. FORESTRY SAWBENCH.
[By courtesy of A. Ransome & Co., Ltd.]

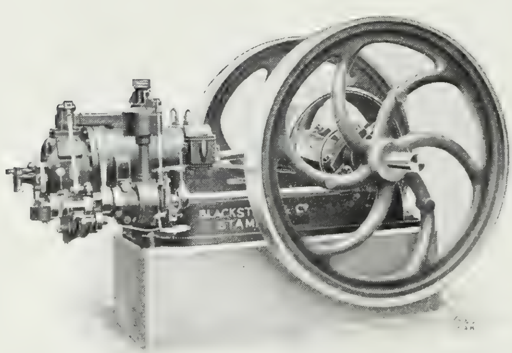

FIG. 6. PARAFFIN ENGINE.
[By courtesy of Blackstones, Ltd.]

[To face next plate.

FIG. 7. QUEBRACHO TREE.
[*By courtesy of Forestal Land, Timber and Railways Co., Ltd.*]

[*To face last plate.*

FIG. 8. GROUP OF QUEBRACHO TREES.
[By courtesy of Forestal Land, Timber and Railways Co., Ltd.]

FIG. 9. LUMBERMEN STRIPPING QUEBRACHO LOGS.
[By courtesy of Forestal Land, Timber and Railways Co., Ltd.]

[To face next plate.

FIG. 10. TRAIN OF QUEBRACHO LOGS.
[*By courtesy of Forestal Land, Timber and Railways Co., Ltd.*]

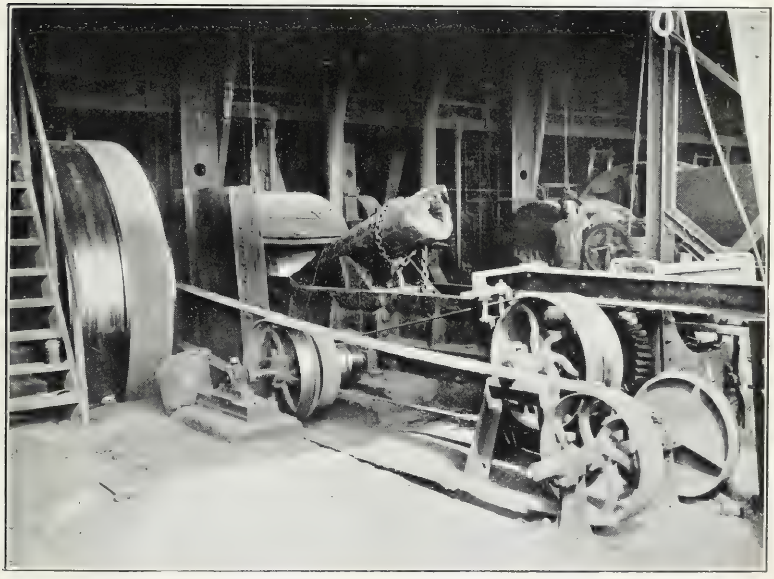

FIG. 11. REDUCING QUEBRACHO LOGS.
[*By courtesy of Forestal Land and Timber Railways Co., Ltd.*]

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CHAPTER II

CRUISING, EXPLORING AND CAMPING

"Cruising" timber—Mapping—Travelling in virgin country—Camping—Travelling equipment—Camp equipment—Malaria—Protection against wild animals—Snake-bite—Travel routine.

THE first step in the exploitation of a forest area is to "cruise" it, that is, to go carefully through it and inspect and estimate the volume and nature of the standing timber to be operated, to note the nature of the country, the possible means of extraction, the approximate cost of extraction, plant, etc. desirable, the suitability of sites for mills and other buildings and kindred matters for the purpose of a detailed report. The actual cruising of the timber is possibly not strictly the work of the Forest Engineer, and the method will only be briefly described here, as more detailed instructions can be found in the many works on forest mensuration.

Cruising

There is no way of inspecting and estimating standing timber and noting the nature of the country properly, other than by walking through it. In most cases, however, to walk through the whole of the forest area about to be exploited, and to examine every tree, would be an impossible task, and therefore some method which will give an approximately correct result must be adopted.

A general survey, however, will be required, and the country should roughly be mapped as the survey progresses.

An experienced cruiser will possibly rely entirely on his own judgment in estimating the timber on the area he is cruising, but without such experience it is safer actually to count and measure trees on portions of the area, averaging and applying the results to the whole. Even in these cases, however, the result after all will only be an estimate, as no experience can assure what a tree will yield when it is sawn up at the mill. The conservative cruiser will in any case deduct 10 per cent. or so even from his own estimate so as to be on the safe side. This work, however, is not designed for the experienced cruiser, and the simplest method of estimating the volume of standing timber will therefore be indicated. If the area is a large one and there exists no detailed survey, it is desirable first of all to explore it generally so as to get some idea of the lie of the land and the distribution of the timber.

A map should be made showing the boundaries of the area, and this map, while meticulous accuracy is not necessary, should be complete enough and detailed enough and on a large enough scale, clearly to show the configuration of the country. Note should be made of whether it is flat or hilly or a plateau, of its altitude, prevailing aspects, the lines of natural drainage, existing roads, water courses, etc.

Note should also be taken of the general characteristics of the soil and rock with a view to road-making and laying railway tracks. The map should show sites of proposed mills, residential and other buildings, drag roads, main roads, forest railroads, chutes, flumes and other necessary constructions. From personal knowledge and reference to such a map the Forest Officer will be able to plan the entire development, to decide the nature of the main and subsidiary methods of transporting logs or sawn lumber, and make the future working a matter of a carefully thought out system instead of a casual and wasteful improvisation as logging problems crop up.

It will be understood that no instructions are intended to be given here as to how to obtain data relating to forest growth, immature trees and so on. This is a part of forest management and is outside the province of the Forest Engineer. The purpose of the cruising here described is to enable the Forest Engineer to decide upon the most economical and efficient methods of logging in relation to the quantity and nature of the timber to be handled and the kind of country to be operated in.

In cruising unsurveyed forest land, a line should be run right through the centre of the area, blazing this base line on the trees or setting up distinguishable marks along its whole length. As a rule it should be enough if 10 per cent. of the entire area is cruised, as this should give a sufficiently accurate idea of the whole, so that a 10 per cent. estimate will be described. This is done by cruising strips 66 ft. wide and 660 ft. apart, all running parallel to the base line. Larger or smaller strips and a greater or less distance apart may be cruised if desired.

The instruments required are a compass, a chain or steel tape, hypsometers for measuring heights of standing trees, and tree calipers or girthing tape to measure diameter or girth of the trees.

Girth or diameter measurements of standing timber are taken at breast height, that is, about 4½ ft. from the ground. On sloping ground this height is calculated from the up-hill side of the tree. If there should be any abnormal swelling or buttress at that height, this must be avoided and the dimensions taken at a normal part of the tree. If measuring with tape, one person can measure any girth if he has a small spike to push into the bark at the starting point, on which to hook the ring at the zero end of the tape.

Special calipers for measuring tree diameters are obtainable made of hardwood, but they should not be of a size to measure more than 4 ft., or they become unwieldy. Above this diameter tapes should be used.

With both calipers and tape, care must be taken not to measure obliquely round the tree, but to hold both quite level.

If the tree is not quite circular in shape, two readings, if taken with the caliper, should be made at right angles to each other, and the average recorded. All readings should be taken before removing calipers or tape from the tree.

The cruiser should have four assistants; one, the head chainman, travels along the centre line of the strip, compass in hand, carrying the forward end of the chain. He notes or sketches the distance, the topography, etc., in his notebook as he goes along, showing streams, roads and other features. The rear chainman carries the after end of the chain, and a notebook in which is entered the distances run, as a check on the head chainman. He also enters the trees on the strip, showing species, height, and diameter, as called out to him by the two measurers. These last, one on each side of the centre line, measure all workable trees within 33 ft. of it, thus covering the whole width of the strip between them. They should each carry calipers or girthing tape and hypsometer. Special tapes may be obtained which, when placed round the circumference of the tree, give the diameter in inches, should this measurement be preferred to the circumference.

There are various kinds of hypsometers, but the directions accompanying them are clear enough, so that it is not necessary to occupy space in describing them.

The cruiser himself follows the gang and keeps a check on the whole, particularly on the two measurers.

In chaining, care must be taken not to measure sloping ground on the surface, but to find the approximate level, and chain along it.

With the data obtained, the volume of timber to be handled can be calculated. This can be done from standard volume tables. In order to judge the taper of standing trees, note should be taken when cruising of the taper of any fallen trees of the same nature. A deduction must be made for the thickness of the bark when calculating the volume.

By the time he has gone over the ground to the extent necessitated in order to obtain the foregoing information, the Forest Officer will have a very good idea of the plan on which he is going to work and the methods of extraction suited to the timber, the labour, and the topographical conditions. He will also have noted possible sites for roads, railways and so on, to be checked later, when greater familiarity with the area has given him more detailed information.

Prospecting.

Prospecting for timber or the inspection of virgin forest must entail at one time or another travel in unknown or little known country, and knowledge of how to travel and

Fig. 12. Exploring for Timber: Northern Canada.
Indians Loading Canoes.

Fig. 13. Portaging from one River System to Another: Labrador.

[*To face p.* 10.

FIG. 14. EXPLORING FOR TIMBER IN LABRADOR: A MIDDAY HALT.

FIG. 15. FOREST ENGINEER'S CAMP: NORTHERN CANADA.

[To face p. 11.

camp in such circumstances will add much to the efficiency of anyone engaged in the exploitation of the forest.

Northern Latitudes.

In cold northern latitudes conditions and methods are altogether different from those in Africa, for example, or any tropical country. To take the northern first, travelling in the woods is usually best in the fall. In spring, the snow in the country and the ice on the rivers and lakes are melting. Travelling by canoe is difficult and often impossible, owing to flood and broken ice, and as the whole country is wet and soft, the discomfort in travelling on foot is very great. In summer, the myriads of flies are a terrible pest and their bites cause the most intense agony. Living is next to impossible in the northern woods in summer—the black flies bite all day till sundown, when their place is taken by mosquitos, which bite during the early hours of the night, and then appear to give place to the sand flies, which are a source of exquisite torture till daylight. One cannot work efficiently under such conditions. At the same time it must be stated that no ill effects follow those bites. There is no malaria.

In the fall, about the month of September, the flies and mosquitos have gone, while the weather is at its best and the rivers remain open another couple of months. It is then possible to cover great distances by water, if lakes and rivers are available, as they practically always are.

The best method of getting about is by Indian canoe. Each canoe will carry three men and a surprising quantity of stores, and still draw only a few inches of water. They are light enough to be easily carried for miles over portages from one waterway to another. They are paddled by one man kneeling in the bow and another in the stern, and, if the paddlers are expert canoemen, can be taken through practically any rapids without unloading.

If the trip is to last a considerable time, sufficient dry provisions must be taken, and all these should be sewn up in small canvas bags, to make easy packing, i.e., transport. For constant travelling, tents with ground sheets must be taken as a shelter from rain, but they should be the canvas and ropes only ; poles are only encumbrances, as camp will always be pitched among trees, to which the tent ropes will be made fast.

Camping.

Strong lights for protecting the camp from savage animals are not required in the north, and lanterns for holding candles should be taken—with plenty of candles. Kerosene should be avoided, as it is apt to seep out of the lamps and soak into the food and make it unfit for use. In travelling, camp should always be pitched an hour before sundown, so as to get everything comfortably fixed up before dark, and should always be among thick trees, as a shelter from any storm that may arise. Care must be taken to have it on comparatively high ground, so that there is no possibility of its being flooded in the night-time from any sudden rainfall. If there is any risk of this, a trench should be dug right round the tent to carry off the water. In camping, one man pitches the tents and covers up the baggage with tarpaulins ; another makes the fire and starts cooking and baking ; another cuts firewood for the night, while a fourth cuts and brings in boughs for the beds—short spruce and fir tops for preference. These are laid on the ground sheet inside the tent, not flat, but slanting and leaning against each other, and the result is a soft, yielding bed on which are spread the blankets. If the weather should have been wet or snowy and the boughs are soaking, they are dried by being held in the fire for a minute or two. Camp beds are totally unnecessary for travel such as is described, and are only useless loads, while they give nothing like the comfort of a bed of boughs on the ground. A pillow of canvas stuffed with feathers is a very acceptable addition. In very cold weather a sleeping bag of seal hide or other waterproof material may be carried.

No form of shelter or habitation can be so uncomfortable as a tent. It is bitterly cold in cold weather and insufferable in hot weather. In travelling, however, it must be tolerated.

If cold is to be expected, a camp stove ought to be carried for each tent. It ought not to be a folding one, as it is sure to get knocked about and buckled in travelling and the joints leak and fill the tent with smoke. No elaborate stove is necessary. The best can be made by any blacksmith out of thin sheet iron, riveted together in the form of a box, 2 ft. long by 15 in. wide by 18 in. deep. One end of it is left open and on this is hinged a door of the same iron, covering the whole opening. Near the bottom of the door a hole 2 in. in diameter is cut out. To cover this draught hole, a damper is made of a piece of sheet iron slightly larger than the hole, and hung fairly loosely by a rivet above it. On the top, at the end away from the door, a hole 2 to 3 in. in diameter is cut out, and fitted with a sheet iron ring standing up about a couple of inches all round the hole. This forms a neck on which to slip the lower end of the stove pipe. The latter is made in sections a little less than 2 ft. long, of the same sheet iron, of a little more in diameter at one end than the other so that they fit tightly over each other. There must be enough to reach 2 ft. through the tent roof, which has a hole left in it about 1 ft. square. Into this hole is sewn a piece of tin with a round hole in the centre big enough to let the stove pipe through. When the tent is being folded for transport, care must be taken not to double back the piece of tin and break it. When packing up, the lengths of stove pipe go inside the stove and the whole thing only weighs a few pounds. Tent and stove pipe are seen in Fig. 16.

To use the stove, it is placed on stones on the ground inside the tent and the stove pipe put in place. Dry kindlings and wood are put in and lit and the door is shut, the damper being left a little open at first. When the heat becomes too great, the damper is shut and the burning wood then gives out an even, steady heat. Opening the damper sets up an intense draught and great heat. Pots and kettles can be boiled and any cooking done on this handy stove, which will cost no more than a shilling or two and is more useful for its purpose than any costly patent stove.

A camp oven for roasting and baking is made in the same way, but with one side left out entirely. It can be made to fold flat. The oven is placed in front of the camp fire, with the open side next the fire, with the meat to be roasted or the bread to be baked in it, and the cooking is perfectly done. If good baking powder is carried, the cook can have fresh bread every night by the time the tents are pitched and the camp is in order.

Supplies.

In travelling in northern latitudes, it should be unnecessary to carry any meat, as the party will always carry firearms and game is usually plentiful, but a few tins of corned beef or something of the kind should be taken in case of emergency. The principal supplies to carry are flour, tea, coffee, sugar, hard biscuits, baking powder or yeast cakes, condensed milk, salt, oatmeal, rice and other cereals, butter, jam, soap, towels, matches and candles. Some fat pork should be carried for cooking with, as it is more useful all round than anything else, although lard or olive oil may be used instead. On no account should a plentiful supply of beans be omitted, as it would appear that more travelling and working in the open in a cold climate can be done on this food than on any other. A supply of Bovril should also be carried. For a long absence on a trip such as this, tinned tomatoes are particularly useful, as green food is unobtainable. Jam is useful for the same reason.

Spirits are worse than useless, and it is fatal to rely on them, especially in intense cold. A little good brandy or rum should be carried for emergencies but nothing more. When fatigued and cold and wet after a long hard day, there is no pick-me-up so good as tea, and the traveller should always have this at every halt and as soon as the kettle can be boiled when the stop is made for the night and before supper is cooked.

Equipment.

Cooking utensils should if possible be of aluminium, as they are very light and very strong. Whatever else is omitted, axes are absolutely vital. A small supply of drugs should be taken, but very little of these are required in the northern countries. They are most conveniently packed in the tabloid form of Burroughs and Wellcome. Bandages and other first-aid requisites should also be carried in case of accidents.

The best kind of foot-gear for travelling in the northern woods is the skin boot of Labrador. It is made of soft seal hide and is like a large loose stocking. It ties under the knee with a cord, and is worn with two or three pairs of thick socks. To protect the soles of the feet, a pair of moccasins made of thick cow hide is worn over the skin boots. This foot gear is light and keeps the feet warm and dry. One can walk in water, and there is no slipping on ice or wet rocks, and the soles do not ball up with snow as they would do with boots. Ordinary boots are not suitable for the kind of travel described, and an additional disadvantage they have is that in severe weather one's toes are apt to get frost-bitten, while this is not so when wearing the skin boot and moccasin.

To cover the stores, a large tarpaulin must be carried for each canoe. It may be made of thick canvas rubbed over with two or three coats of boiled linseed oil. A sleeping bag can be made of the same material and lined with several thick blankets. A sleeping bag is only open at one end, into which the owner crawls feet first. The open end should have a flap to come right over the opening and fasten with cords or buttons. If the outer covering is of waterproof canvas, or better still of seal hide, one can sleep dry and comfortable, even if the ground is a puddle of water. Plenty of blankets should be carried.

A quantity of spare rope and line is also necessary.

If expert woodsmen accompany the party, they will find in the woods materials for repairing damaged canoes, worn-out footgear, and almost everything else.

If one should be travelling in the winter when the rivers and lakes are frozen and snow is deep in the country, travelling is done on snow-shoes and the place of canoes for transporting stores is taken by sleds drawn by men or by dogs, if the latter can be obtained. Especially towards the end of the winter, travelling should be done in the morning and the early hours of the day when the crust on the snow is hard after the night's frost and will carry a load. Even in winter, the mid-day northern sun has the effect of softening the crust and making walking uncomfortable and difficult. If walking on frozen rivers or lakes, one should always carry a stick about 6 ft. long. On doubtful ice one should tap it sharply as far as the stick will reach. If it gives out a clear ringing sound the ice is safe ; if a dull sound it is dangerous.

Tropical Latitudes.

In a tropical country conditions are different, and methods of travelling have to be adapted accordingly. This is particularly the case in less healthy places.

In the north, the climate and the life generally spell robust health, and the medicine package will probably never be opened, or only to deal with the simplest ailments. In a tropical country, the very first consideration must be given to health precautions. The medicine chest should be selected with very great care, and here again Burroughs and Wellcome's tabloid drugs are best and they meet every requirement. In a cold country a fatiguing day or a wet skin does no harm, and one is all right after a good rest. In a malarious country, on the other hand, a fatiguing day or a chill may mean a dose of malaria and serious illness. After a tiring day a stimulant at sundown when camp is pitched for the night and before dinner, is often the means of restoring one's energies, making one eat and warding off serious trouble. The frequent use of stimulants, however, and especially their use in the heat of the day, is fatal.

Malaria.

The writer has lived for several years in the most malarious countries in the world, and he does not know of any means of warding off the trouble in a very unhealthy country. Common advice is to take several grains of quinine every morning, and this used to be the rule on the West Coast of Africa when he lived there. He never took any quinine at all, except on the only two occasions in the whole of his

Fig. 16. Forest Engineer's Camp in Far North.

[To face p. 16.

FIG. 17. FOREST VILLAGE: WEST AFRICA.

[*To face p.* 17.

residence there when he actually had malaria, and he never knew habitual quinine takers escape any more than anyone else, while many of them became nervous wrecks. Contrary to a generally accepted rule, instead of drugging he believed in feeding particularly well on plenty of the best of food in the tropical malarious country, much more so than in a healthy climate. He tried this plan with himself and all his white assistants in a most unhealthy part of West Africa, and all had excellent health, and were able for, and accomplished, continuous hard mental and physical work.

If malaria is contracted, the first thing to do in any case is to take a saline purgative and go to bed with plenty of blankets, and then stay there till better. Ten grains of Phenacetin should be taken to induce perspiration, which results in a lowering of the temperature, but is no cure. This drug should always be obtained in the Tabloid form with Caffeine, as alone it has a depressing effect on the heart. After that the patient must be guided by someone else than the writer as to the taking of quinine or any other drug. The very great thing necessary is to keep up the system, and after malaria to build it up again with Bovril, boiled milk and similar light foods till the patient is able to resume his old routine. Malaria has a very depressing effect which, however, quickly passes, and one is often out and about the day after he has made up his mind he is at death's door.

Malaria is carried by a mosquito, and as these pests do not come out in the bright sunshine but only attack one at night, the traveller in malarious country must carry a camp bed and mosquito net. The net in use must not be allowed to trail on the ground, but be kept tucked in all round under the mattress, or the mosquitos will crawl up inside it.

In camping, the tent door should be closely shut up about an hour before dark, to exclude mosquitos, and not opened till after sun-up in the morning, but the net over the bed should be used all the same. It is unwise to camp anywhere near a native village, as natives in a malarious country are all carriers of the disease. The camp should never be in thick jungle or bush, but should be in as airy a situation as possible, although it may be under the shelter of one large spreading tree, and should never be within three or four hundred yards of a stagnant pool or any still water, as it is there the mosquito breeds.

After malaria, the most urgent disease to provide against is dysentery. This can usually be accomplished simply by boiling all drinking water, no matter whether it is drawn from pool, well, or clear running stream. This precaution should never be omitted. The writer personally has no belief whatever in any filter he has ever seen. If milk is obtained from native villages, it should never on any account be used unboiled.

Snake-bite, etc.

One danger the writer never omitted to provide against was snake-bite, and he must confess to an intense fear and horror of the reptile. Permanganate of potash, a lancet, and tape for ligatures should always be carried on the belt and never laid aside, as an antidote is useless unless applied immediately the snake has bitten. The complete outfit for the belt can be obtained in the shape of a little metal tube like a whistle, with a light chain at one end to hang it to the belt. In the tube are a number of pellets of permanganate and a small sharp lancet. If one should unfortunately be bitten, the wound must be lanced as deeply as possible, the cuts running the way of the tendons, and a pellet of permanganate rubbed well in. A ligature of tape is twisted with a stick as tightly as possible round the limb between the wound and the heart. If the person bitten shows signs of collapse, he may be given a slight stimulant, but contrary to a common belief, this is not the slightest antidote to the poison. He should be taken to camp as quickly as possible and a serum injected. For this purpose in a snake country, the writer always carried Fitzsimmons' Anti-Snake-Bite Outfit, and this should always be kept in camp, and if used in time has never been known to fail even after a bite from the deadliest snake. Clear directions accompany the outfit, which is contained in a

FIG. 18. TIMBER "CRUISING" IN WEST CENTRAL AFRICA.

[To face p. 18.

Fig. 19. Thorn Fence Protection against Wild Animals: Africa.

[*To face p.* 19

box small enough to go into the coat pocket. Permanganate only neutralises the poison it actually comes in contact with ; Fitzsimmons' serum goes out and meets and destroys it. The ligature must be gradually slackened and must not be kept on tight more than an hour, or mortification of the limb may result. Mr. Fitzsimmons is the famous Curator of the Port Elizabeth Museum, and perhaps the first authority in the world on snakes and snake-bite.

Stings and bites of poisonous insects are seldom fatal although painful, and they should be treated with permanganate and ligature.

If one is unfortunate enough to be bitten or clawed by a carnivorous animal the wound should be washed at once with a very strong solution of permanganate, as the claws and teeth of such animals are always exceedingly septic, and unless even slight wounds are at once thoroughly disinfected, septic poisoning and often death result.

The stores to be carried in an expedition in a tropical country are of much the same nature as those already detailed. Beans and pork may be left out, and canoeing is unlikely. Almost the whole of the countless miles travelled by the writer in the tropics have been on foot, and his stores, etc., carried on donkeys or by natives.

Protection.

In lion country like so much of Africa, and in any country where savage animals abound, while one is absolutely safe from harm in the day time, it is necessary to carry strong lights to protect the camp at night. Fires round the camp are insufficient protection. As long as they blaze up they are all right, but they die down, and the fatalistic native does not worry his head about them or stay awake to keep them replenished. When camping in such country, the halt should be made early in the afternoon. Plenty of thorn bush should be cut to make a ring fence round the camp (See Fig. 19). The fence should be six feet high and several feet thick, and a space should be fenced off inside for the donkeys or other transport animals, which should be driven in before dark and given a good quantity of grass which has been cut for them to eat in the night. After all is cleared up for the night, the entrance to the ring is closed up by one or two large branches of thorn trees, and the occupants are perfectly safe. No lion will penetrate such a fence even to secure his favourite tit-bit, the donkey. An additional protection, much better than fires, is to hang several thoroughly dependable lanterns throwing a strong light at intervals round the outside of the fence. No beast of prey, especially of the cat tribe, appears to like the light. Inside a camp of this nature, in fact the actual one seen in Fig. 19 in a country infested by lions, the writer, his natives, and his donkeys have often slept unconcernedly, while a troop of lions have been roaring or grunting around for hours at a time, within a dozen yards, as the spoor showed next day, in a vain endeavour to stampede the patient little donkeys.

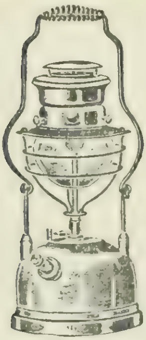

FIG. 20. SAFETY CAMP LAMP.

[By courtesy of T[illegible]y Lamp Co.]

The lanterns in use necessitate the carrying of kerosene, but this cannot be helped as they are necessary for safety. As one's life may depend on them, they should be in the circumstances the best obtainable and the simplest and most reliable in action, and possessing an intensely strong light such as the lamp illustrated in Fig. 20. The writer has often been overtaken by dark in lion country when travelling light without a tent and with only one or two boys and it has been impossible to put up a thorn fence. He has found a couple of these lights alone sufficient protection. As open a space as possible was always selected with no long grass and no cover for the lions or leopards to sneak up unnoticed, and a couple of lights hung up on sticks above the sleepers. In the morning the spoor of the lion or leopard has been noticed not many yards away where it has been reconnoitring the sleeping camp, but the animal would not venture into the full glare of the light.

It is an old-fashioned belief that if a horse-hair or coir rope is placed on the ground in a circle round a tent, no snake will cross it. This is derided by many would-be authorities, but it is quite likely to be true. A snake's outer covering consists, underneath at least, of alternate rings of hard skin with which he moves along the ground, and rings of very fine skin between. The fine skin is very sensitive and the snake much dislikes having it pricked by the countless prickles of the rope, and therefore as soon as he feels them he draws back.

Travelling.

Having planned all precautions for health and safety, the routine of travel may now be taken up. Even more than in a cold climate, travelling or work of any kind should never be begun on an empty stomach. The best plan is to have a breakfast of porridge and milk, eggs, etc., and tea or coffee before daylight, by which time everything ought to be packed up ready for an immediate start, so that the travelling can be done in the coolest hours of the morning. A halt should be made about eleven for two or three hours to rest both men and animals in the heat of the day, and a substantial meal should then be eaten. Then two or three hours' more travel, and the final halt in plenty of time to fix up camp before dark. Tea as a reviver should again be got ready as soon as the kettle can be boiled, and then is the time for the warm, not cold, bath, which should never be omitted, and a change into dry clothes. By this time dinner or supper will be cooked and ready, after which one is generally quite prepared to crawl under the mosquito net and go to bed.

The clean white cloth for the table, serviettes, clean cutlery and glasses, all the civilised amenities of the table, are easily carried and not only have a beneficial effect on one's spirits but on actual physical health.

A good cook is essential. All meat should be well cooked, and especially the meat of any animals shot for food. These are often infested with parasites, and if the meat is under-done it is dangerous.

Meat will not keep in a hot country, but the biltong of the South African Boer is easily made. The meat of a newly killed animal is cut into strips and soaked in brine.

Salt and pepper are then rubbed thoroughly in and the meat is hung up in the shade till it becomes as hard and dry as a piece of wood, when it will keep in first-class condition for years.

Equipment.

Tents should be of green rot-proof canvas, and all folding camp furniture, such as beds, table, chair, bath, etc., of the same. Stores cannot be packed in the nice canvas bags of northern travel, so easy to carry and so comfortable to rest on. They must be in strong wooden boxes with hard, uncomfortable corners, and no box should have more than the recognised load of 50 lbs. weight.

In purchasing camp equipment and outfit only the best should be obtained, as there is no possibility of replacing faulty goods. Well-known firms like Silver, of London, are reliable guides for the traveller.

As regards clothing, one's ordinary old clothes are all that should be necessary. The writer does not follow the prevailing fashion of wearing shorts and knickers. Many of the grasses through which one travels have sharp seeds like the black-jacks, which are easily detached in rubbing against them, and bury themselves deep in the skin in hundreds, setting up most intense irritation and often festering sores. He prefers khaki drill trousers, which resist the penetration, good boots and leather leggings. Top boots are useless, hot, and uncomfortable. Leggings are necessary in snake country, as a snake usually bites low and his teeth will not penetrate the leather. Socks should be thick, and boots should be greased inside and out when tramping, as the care of the feet is a matter of the utmost importance. Head-gear is necessary in the tropics, and should be the best procurable sun helmet. Mosquito boots, long boots like loose stockings of soft kid or chamois skin for wear while sitting about the camp, are a great comfort and will prevent the jigger or sand flea getting under the toe nails, laying eggs there and gradually causing the eating away of the flesh.

In a tropical country a bodybelt should always be worn. It should be made of thick flannel, doubled or trebled to a

Fig. 21. Prospecting for Timber on Selati River : South-East Africa.

[To face p. 23.

width of nine or ten inches and well quilted, and fastened round the body by buttons. The usual knitted shaped bodybelt sold by most outfitters is quite useless, and when one is heated with travelling, it generally wrinkles up like a rope. To be of any use, the belt must be stiff and wide enough to cover all the vital organs.

If horses, donkeys, or other animals are used for transport or for riding, they must be carefully examined every night to make sure there are no galls or sores under the saddle. If one's horse is galled, one must just use his own feet till the sore is healed, while if pack animals are galled, they must not be loaded for some days.

In some parts, it is usual for the white man to travel in a machila, that is, a hammock slung on a pole with an awning over it. Natives carry the hammock by the ends of the pole and cover the ground very quickly. In travelling in thick jungle, however, the occupant of the hammock is very apt to get scratched by bushes on either side of the path, as the bearers are not particularly careful.

With the precautions and hints mentioned in this chapter, the Forest Officer exploring any new country for timber should be able to do so with efficiency and a fair amount of comfort.

In India, the Forest Officer, when on tour, either makes use of the numerous Rest Houses with which many of the forest divisions are fully provided, or carries tents with him. Perhaps in no other country in the world is camping with tents so well understood or so comfortable as in India. This may be partly accounted for by the innumerable capable and well-trained servants of one kind and another who accompany the European. In other countries the latter is not so fortunate.

The tents used are double fly ones of commodious size, and provide quite a comfortable residence. Small tents are also carried for the servants. The method of carrying officers' equipment while on tour varies in different parts of the country, viz., by elephant, camel, mule or pony, native boat or launch in the river districts, or by coolies. The method of procuring the necessary porterage when moving camp is well understood in the country, and usually presents no difficulty, the rates to be paid being more or less fixed in the particular locality.

The construction and upkeep of the Forest Rest Houses are usually undertaken by the Forest Department, the type of building and materials used varying in the different provinces.

There is little "roughing it" in the Forest Service in India. The country is not a new, unexplored one, but of a very old civilisation, and for generations officials and civilians have been used to a degree of comfort in travelling unknown to the writer anywhere else. Still, going without this comfort, and opening up new country where it does not exist, is not without its fascination.

CHAPTER III

SURVEYING RIVERS AND STREAMS

Examination of rivers and streams for purposes of driving or floating logs and for power.

In most timber countries rivers or streams of some description exist. If these can be utilised for driving or floating logs, they form a convenient and cheap method of transportation. The term "driving" is applied to the sending of logs singly down a river or stream which is too rough to allow them to be assembled and rafted; "floating" logs is sending them down in rafts, and can only be done when there is a good depth of steady water and there are no obstacles. A river which is wide, deep, and steady enough to float rafts will probably not require much to be done in the way of improvements beyond blasting away an occasional rock.

On the other hand a river or stream down which logs can be driven is seldom naturally in a condition for this, and various improvements have usually to be undertaken for the purpose of making driving possible. In driving logs, these have to be looked after from the time they are put in the water till they arrive at the end of the drive in a lake or bay, or at the mill.

A preliminary examination should be made of any rivers or streams issuing from the area to be logged, to ascertain if conditions for driving are favourable, and, if not, what improvements are necessary to make them so. As a rule, driving timber is a seasonal operation and is only undertaken during a rise of the river due to melted snow in the mountains or seasonal rains, so that the lowest state of the river need not be taken as the basis on which to form plans.

In examining a river or stream note must be taken of any backwaters. These are boomed off, as described in the chapter on river work, as, if left open, logs would lie in them and strand when the water fell, causing much trouble and expense in again moving them.

Rapids in a river are generally caused by a sudden narrowing or shallowing of the bed at an abrupt change in the level, and, owing to this and unseen obstacles, it may not be possible to send logs over the rapids at all, the more so as a wild rapid is an impossible place for the men working the drive to go into to keep logs moving. It is a favourite place for a serious jam to occur. If it is quite impossible to negotiate a rapid, the banks should be inspected with a view to putting in a wooden log sluice from above the rapid to below it, so that the logs may be sent round. The construction of the log sluice is shown in Chapter X and the cost is very much less than cutting a canal would be, especially as the sluice may be carried easily through rocky country where the cost of canal cutting would be prohibitive.

Instead of the river suddenly narrowing, there may be places where it spreads out over a very great area and where the depth and speed may in consequence be so much reduced as to render driving impossible. Here it will probably be feasible to make an artificial channel by erecting inexpensive cribwork embankments to confine and deepen the water until the natural bed again becomes suitable for working.

No bend in the river must be so sharp as to prevent the clear passage of the longest logs it is intended to send down. Too sharp a bend may be remedied by cutting away part of the bank.

Rock obstacles, either above or under water, can only be removed by blasting. The method of drilling and blasting and handling dynamite, described in the chapter on forest railway construction, is applicable to river work as well, but this latter should only be undertaken at the season when the water in the river is at its lowest. Should the hole which is being drilled be a wet one, this does not affect the power of dynamite, which can be used completely under water, but if it is the fuse must be a waterproof one.

When inspecting a river, a sharp lookout must be kept for snags and sunken logs. These are sure to exist, and unless they are removed, they are apt to cause a jam and hang up an entire drive. Unless they can be hauled out to the banks, they must be removed or broken up by exploding dynamite cartridges under them.

Any trees which have fallen on the banks and lie partly in the river must be removed.

If a stream has a narrow bed with not too steep a fall, and the depth of water is insufficient for driving, which may be a desirable method of transportation, the stream may be turned into a driving river by the construction of a series of dams at convenient places. These dams need not be of expensive construction, but can be built of cribwork as described in Chapter X. The levels of the stream would have to be taken approximately and suitable sites selected for the construction of dams to hold up sufficient water to give depth for driving.

Any river improvements would of course be constructed when the water in the river or stream is at its lowest.

If driving is to be undertaken and the cost of river improvements be incurred, an inspection of the surrounding country should also be made to ascertain the entire catchment area drained by the stream. It is not advisable to base costly plans on the amount of water in the stream at any given moment, but the average rainfall and the catchment area should be ascertained, so that it may be known if there is a possible reserve, and approximately, what the reserve amounts to.

It is very desirable to create an artificial reserve of water for driving, if a natural one does not exist in the shape of a lake or pond at the head of the drive. If the stream empties out of a lake or pond, the amount of water in the latter may be increased by constructing an embankment or dam at the outlet, if the configuration of the ground is suitable. Raising the level of a considerable area of water, even a few feet, results in a large increase of storage capacity.

If no lake or pond exists, one may be created by damming the stream above the head of the drive, and data for this purpose should be obtained during inspection. It may also be possible to dam tributary streams and so create subsidiary reservoirs along the course of the drive if the latter is a long one, for providing additional supplies of water for the main stream as required.

It is better if possible not to depend entirely on the seasonal rise of the stream for driving but to create storage, so that if a dry season or only a partial rise of the stream should occur, the drive need not be entirely hung up as would otherwise be the case. Sites for damming as well as for deepening the stream should therefore be looked for. The amount of artificial storage along the stream depends upon the length of time during which driving is required and the duration and frequency of rains. What is to be kept in mind is that as clear a run as possible for the logs should be provided. It is wonderful how quickly a jam is built up after only one single log is caught by some obstacle. The logs pile on the top of each other in the utmost confusion, and quickly become so entangled, that in many cases they can only be separated by being blasted with dynamite, a proceeding which of course entails heavy loss from the breakage of logs.

The only other purpose for which a river or stream need be examined, apart from affording facilities for domestic water supply, is for its possibilities of power development.

Water Power.

To ascertain approximately the power a stream is capable of developing, the first step is to find the area of the water contained in the stream at any given point. It does not really matter at which point, so one may be selected that is convenient and safe for wading, as only by doing so can the necessary data be obtained. If the current at the place selected is very strong, a stout stick should be carried when wading with which to prop oneself up against the stream, as shown in the illustration (Fig. 22).

The width of the stream is measured in feet. The average depth in feet is then ascertained by taking the depth of water at stated intervals—say, every 3 or 6 ft.—across the stream in a straight line between the two points at which

FIG. 22. MEASURING CURRENT FOR POWER: NEWFOUNDLAND.

[*To face p.* 28.

FIG. 23. 4-MILE PIPE LINE OF WOODEN STAVES: FOR POWER.

[By courtesy of British Columbia Government.]

[To face p. 29.

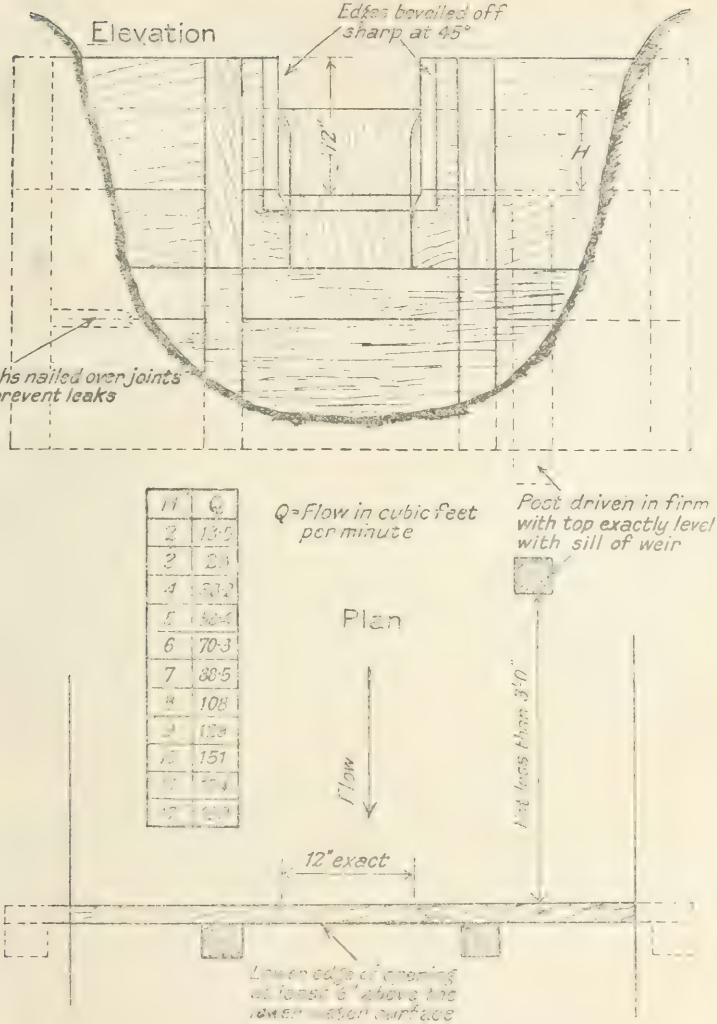

FIG. 23. STREAM GAUGING WEIR.

[By [illegible]]

the width was measured. Adding together the whole of the depth measurements and dividing by the number of times the depth was taken will give the average depth. The width multiplied by the depth will give the area in square feet of the water in the stream at the given point.

The number of cubic feet passing in the stream per minute must now be obtained. A piece of wood or a float of any kind is thrown into the stream, and the time taken by it to pass from one given point measured in feet to another given point noted. This should be done several times at the same place and the average noted. From this can be calculated the speed of the current per minute. The area of the water in the river in square feet is now multiplied by the speed of the water in feet per minute, this giving the number of cubic feet per minute in the stream.

The power of the water is actually the number of cubic feet per minute passing in the stream, which we shall call Q, multiplied by the fall in feet, which we shall call F. Assuming that there are 62.4 lbs. in each cubic foot of water, the number of foot pounds per minute is therefore $F \times Q \times 62.4$. In each H.P. there are 33,000 foot pounds per minute.

$$\frac{F \times Q \times 62.4}{33{,}000} \text{ thus equals the water H.P.}$$

Assuming that a safe efficiency for small water turbines is 50 per cent., the following is therefore the B.H.P. of the turbine :—

$$\frac{F \times Q \times 62.4}{2 \times 33{,}000} \text{ or roughly } \frac{F \times Q}{1{,}000}$$

The fall obtainable at any suitable site must be ascertained by taking the necessary levels.

The foregoing is likely to give the result correct enough for ordinary forest work, but if a more accurate measurement of the water is necessary, a stream gauging weir must be constructed of timber as shown in Fig. 24.

The letter H in inches corresponds to the height of the water above the bottom in the opening of the weir. This measurement is obtained from a post which is driven in not less than three feet back from the weir, and which stands exactly level with the sill of the weir. Putting a rule or stick on the top of this post and taking the height of the water above it, gives the height H. After the quantity of cubic feet per minute is obtained, the procedure already indicated to find the B.H.P. is applied.

If a stream is to be used for power purposes, an examination must be made to find suitable sites for power dam, power house, and so on.

CHAPTER IV

FELLING AND CLEARING

Felling—Trimming—Cross-cutting—Hand and power sawing—Appliances and tools used—Care of saws, etc.—Stumping—Dragging.

TREES are almost entirely felled by hand power, by axe and saw. Power saws are used for the purpose of felling trees, but they do not seem to be very successful or to have come into very general use. They are heavy and awkward to move about, especially among brush or thick undergrowth, while as they cannot be moved hurriedly out of the way of a falling tree, they are apt to be exposed to damage. Nothing has yet equalled the axe and saw wielded by competent fellers.

Girdling.

Trees, when girdled, are so treated principally for the purpose of enabling them to be floated, if their weight when green would cause them to sink in water. A ring is cut with the axe all round the tree through the sap wood right to the heart wood. This girdling should be at the point where the tree will ultimately be sawn through for felling. It is girdled in the case of some timbers from a few weeks before the felling, to as much as three years or more in the case of teak. Girdling lightens the log, and has also the effect that the heart wood, not being green, is not so apt to bind the saw.

Throwing.

The direction in which a tree falls may be influenced to some extent. Generally it will fall in the direction in which it leans. If the lean is not very pronounced, it may be determined by holding up an axe loosely by the end of

FIG. 25. MONKEY JACK THROWING TREE.
[By courtesy of Messrs. Treseder.]

[*To face p.* 32.

FIG. 25A. FELLING TREE 51 FT. IN CIRCUMFERENCE.
[By courtesy of British Columbia Government.]

[To face p. 33.

the handle and allowing the axe head to be the plummet. The axe will be perpendicular, and by thus holding it between the eye and the tree, the direction in which the tree leans will be apparent. If the tree is straight or leaning very slightly, and the crown is fairly well balanced, it can be thrown in any direction by driving wedges into the saw cut. If the lean is very pronounced, it can be thrown either in the direction of the lean or to either side. If the crown is very much heavier at one side than the other, the tree will be top heavy on that side and will so fall. A patent tree feller has been brought into use by means of which a tree may be thrown in any direction. It has jaws which open out on a screw, turning by means of a lever. A notch is made where the saw cut begins, on the side opposite the direction in which the tree is desired to fall. The points of the jaws are inserted in the notch, and, on working the lever, they open out perpendicularly and throw the tree away from them.

The same purpose may be served by a stout pole from 10 to 15 ft. long with a spike in one end. The spiked end is placed against the tree at a suitable height above the ground, the pole being slanted out from the tree till it is just clear of the ground. A short pole is held with one end in the ground at a point slightly nearer the tree than the place reached by the longer pole. The end of the latter is now placed against the shorter, a little above the ground, and the top of the shorter one pushed in the direction of the tree. The leverage exerted will throw the tree away from the lever.

A much more powerful appliance for the purpose of throwing trees in any desired direction is the monkey jack made by Messrs. Trewhella Bros. It is simple in construction and operation, and is useful for the purpose of any ordinary jack in lifting heavy weights, turning heavy logs and so on. For the purpose of throwing timber, a steel extension piece is used with a sharp point on the upper end. This is rested on the lifting claw of the jack and rises with the claw. The upper pointed end of the extension piece grips the trunk as shown in the illustration (Fig. 25), and when the lever is worked, pushes the tree with immense force. By means of this appliance a tree can be thrown in practically any direction, even against its natural lean.

In controlling the direction of the fall, care must be taken that the tree does not jam in another standing tree or damage any young timber which is to be left standing. It should be felled so as to be parallel, if possible, with the skid or dragging road, as this simplifies handling. If felled on a steep slope, trees should be thrown with their tops uphill, if possible, but hauling up is more difficult if the top comes first. If thrown so as to fall downhill, they have much further to fall and incur greater risk of breakage in their fall. If this has to be done for any reason, no man or animals should remain in the way below them, as they may start to slide as soon as they fall.

Felling.

To fell a large tree a wedge-shaped notch is made on the trunk on the side on which it has to fall. The base of the notch is horizontal and is cut with a saw to the depth of about a quarter of the diameter of the tree, and two or three inches below the ultimate saw cut for felling the tree. The notch is then completed with an axe. The felling saw cut is then begun on the side opposite to the notch, by two men with a cross-cut saw between them. When the saw is buried wedges are driven in behind it to prevent it binding. As the saw cuts through, the wedges are driven after it by blows from the back of an axe. Sawing is continued through in the same line to meet the notch, and when this is approached the tree begins to fall, when the sawyers withdraw the saw and stand back into safety.

If the diameter of the tree is greater than the saw will take, the sawyers first saw as deeply as possible, one cut on each side of the notch and at right angles to it and finish up by sawing towards it from the opposite side. The cut should be at the ground level or as near as possible, unless there is some condition in the butt which makes this uneconomical. Felling with the axe alone is wasteful.

When a tree is down it is trimmed by having the unmer-

Fig. 26. Logging in New Brunswick.

[By courtesy of Canadian Government.]

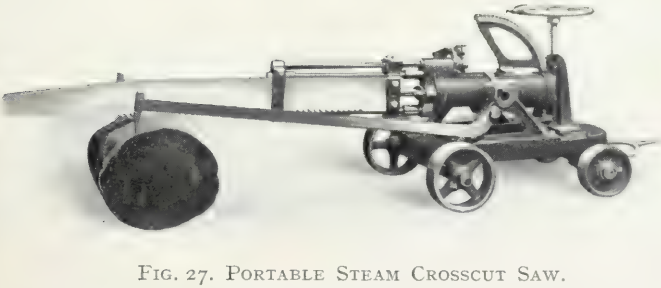

Fig. 27. Portable Steam Crosscut Saw.

[By courtesy of A. Ransome & Co., Ltd.]

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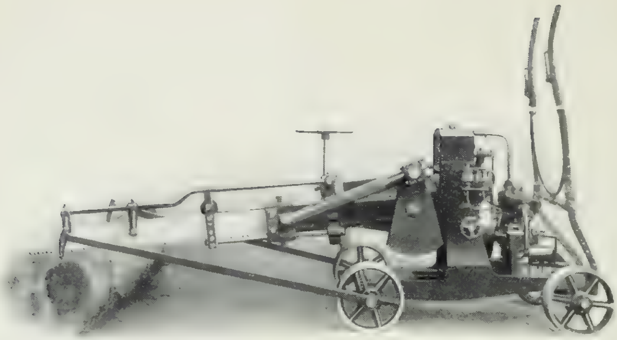

FIG. 28. PORTABLE PETROL CROSSCUT SAW.
[*By courtesy of A. Ransome & Co., Ltd.*]

FIG. 29. LOG RINGED OF BARK FOR CROSSCUTTING: POLAND.
[*By courtesy of Century Timber Corporation.*]

[*To face p.* 35.

chantable top and all the branches chopped off. It is then hauled out whole, or cross-cut where it lies into suitable length logs for the purposes for which these are to be used. Limbs and tops which are too small for any other purpose are cross-cut up for pulp wood, cord wood, charcoal or distillation.

Power saws for cross-cutting felled trees are in common use on fairly flat land, and are suitable for this purpose both from the point of view of economy and efficiency, such as the machine made by Ransomes of Newark (Figs. 27 and 28), which will cross-cut logs up to 6 ft. in diameter. It can be mounted on road wheels and easily moved about in the woods, or it can be fitted with wheels for a rail track. The rails may be made of hardwood sawn in the forest. The lengths into which trees are to be cross-cut, or whether they are to be cross-cut at all, will depend on the purpose for which the timber is required, or on the method followed in hauling the timber out of the forest.

Crooked trees, unless to be floated or rafted, or trees with some defect, should be sent to the mill without cross-cutting if that is possible, as an experienced sawyer can saw these to much greater advantage and with much less waste at the mill than the felling gang is likely to do in the forest.

Logs which are intended to be floated or rafted should not be cross-cut into short lengths unless crooked, as the longer the logs are the stiffer the raft will be, while the handling of a given number of long logs is easier and cheaper than the same volume made up of short lengths. However, all the factors governing the lengths of logs must depend on local conditions and requirements.

Cross-cutting, etc.

If definite lengths are given for cross-cutting for the sawmill they must be rigidly adhered to, or much waste may result where the log is cut too short or too long. A fixed margin of three inches over the required length should be insisted on in every case and this should cover all emergencies. If less than this, waste may occur, as it often happens that from the position in which the tree lies the cross-cutters are not able to saw exactly at right angles to the length, while the ends of the log are often frayed in dragging. Any margin greater than this is definite waste.

Where a part of a tree may be defective or knotty and the remainder clean, the latter portion should be completely separated in cross-cutting, as its value is then increased. If this is not done, its value as a log will be that of the inferior portion.

When cross-cutting, the saw cut is kept open by means of wedges as in felling. Unless the tree is lying solidly on the ground, it must be held up at the saw cuts by logs or some such support pushed underneath. If this is not done, not only will the saw bind, but the timber will split before the saw is through, and waste will result.

On some kinds of timber the bark dulls the saw, and where this is the case the bark is chopped off round the position of the saw cut before the sawing begins. See Fig. 29.

If the logs are barked before removal from the forest, they drag more easily.

Felling any area should begin at the farthest away point from the skidway or roadway while the ground between is clear of cut tops and limbs, otherwise dragging becomes much more difficult. All the lop and top should be left behind the felling and dragging.

It is difficult to give any reliable figure as to what the output of a felling crew ought to be. So much depends on the size of the crew, whether the timber is hardwood or softwood, whether the felling is on level ground or on a hill-side, the weather, the size of the timber, the thickness of the brush, extent of windfalls, climate and so on.

Tools.

The principal tools used in the woods are the felling axe, the head of which is generally about 4½ lb. weight ; the two-handed saw, which may be any length from 5 ft. to 18 ft. ; the peavey, a pole about 5 ft. or 6 ft. long with a spike and a hook at one end, and the canthook for turning logs (Fig. 30).

Wedges are used to drive after the saw cut, both in felling and in cross-cutting felled timber to prevent the saw binding. They are also used to drive after the saw in felling timber to throw the tree in any desired direction. They may be made of hardwood or of metal and anything from 6 in. to 1 ft. in

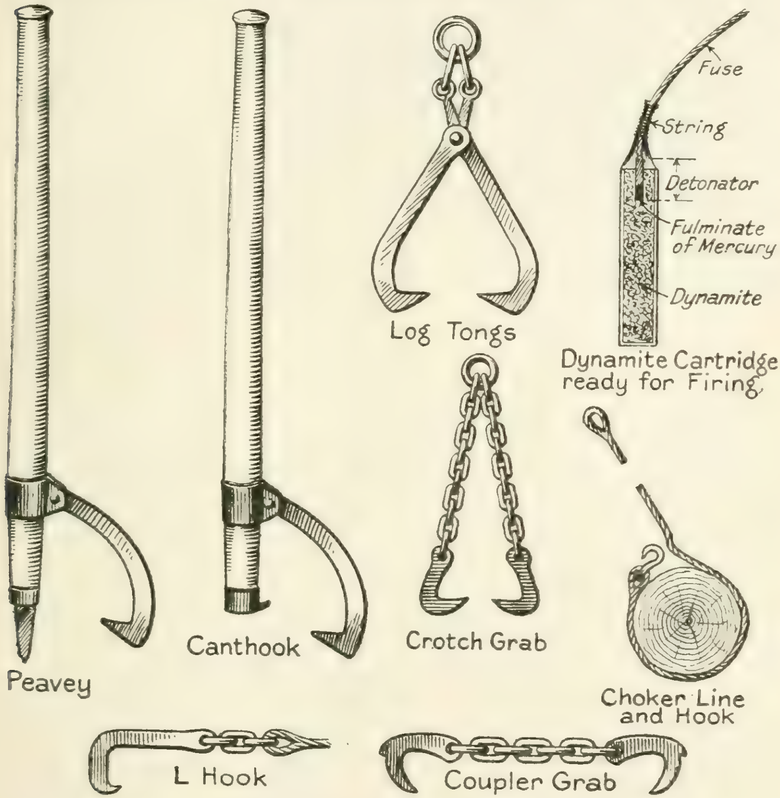

FIG. 30. TOOLS AND APPLIANCES.

length and about 1 in. thick at the head. If made of metal, they should be roughened with the point of a chisel so as to grip the wood as they are driven in, or the weight on them may push them out again. They are driven with the back of an axe.

If the timber is resinous, the resin collects on the saw and makes it stick in the saw cut. This is corrected by frequently rubbing the saw with kerosene. The length and width of saws vary to suit varying requirements. The blade is usually curved outwards at the teeth side, as this makes easier running. It is thinner at the back than at the toothed edge to reduce friction and make the work easier. Saws may either have uniform teeth all the way along the blade, or the teeth may be arranged in sets of two or three cutting teeth with a raker tooth between each set. The purpose of the raker is to clean the sawdust out of the cut. Sharpening these saws requires more skilful operators than those without rakers, and unless these are available it is better to use the saw with cutting teeth only.

Pine, fir, etc., are easier to saw than hardwood, while poplar is about the most difficult of all owing to its texture. In sharpening the saw all the cutting teeth must be of the same length or the whole power of the saw is not used. Each tooth is sharpened to a point and bevelled, the bevel being adapted to the class of timber being dealt with. The saw must also be set, that is, each alternate tooth is forced slightly to one side and the remaining teeth to the other side. This makes the saw slightly wider than the thickness of the blade and makes work easier. The least possible set should be given, as the greater the set the heavier the work of the saw.

Stumping.

It will be convenient here to describe a quick and easy method of stumping. It may be desirable in any forest extraction operation to pull out stumps, and in any case when constructing roads or railway tracks through the forest and clearing building sites, it must be done. In such cases it is easier to uproot the whole tree, and top and cross-cut it as it lies. The method to be described is, both for stumps and standing trees, practically the same.

Stumping, as a rule, is a slow, expensive, and laborious operation, but these drawbacks have been eliminated by an ingenious monkey winch made by Trewhella Bros. An illustration of this winch is given (Fig. 31), as well as others showing it in operation. It is light enough to be carried

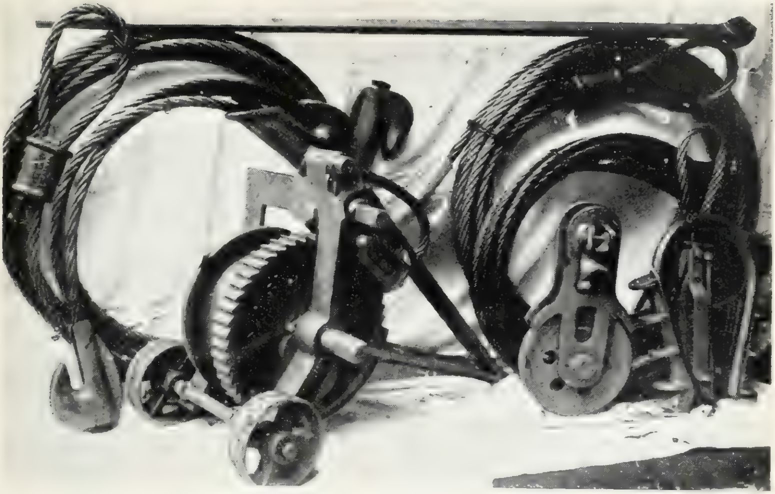

FIG. 31. MONKEY WINCH.
[*By courtesy of Messrs. Trewhella.*]

FIG. 32. MONKEY WINCH UPROOTING TREE.
[*By courtesy of Messrs. Trewhella.*]

[*To face p.* 38.

easily by two men and needs no special preparation made for it, while it is extremely simple in operation and strong in construction.

It consists essentially of a couple of wire ropes, the drum rope and the pull rope ; a small winch worked by a lever ; a snatch block, and a grab for taking up the slack of the pull rope, as shown in the illustrations. The pull rope is hitched round the tree to be pulled out, at a height above the ground of from six to twenty feet. The higher it is the greater is the power exerted. The winch is anchored by the drum rope to another tree or stump close to the ground. The snatch block is inserted and the grab attached to the snatch block. The pull rope is now pulled up and gripped by the grab and all is ready for the pull. A log should be laid crosswise at the root of the tree to be pulled out, and when the tree ultimately falls it trips over it, and the last of the roots will be wrenched clean out of the ground instead of breaking off. When all is ready a couple of men work the winch lever, a tremendous power is exerted, and the tree falls to the pull.

If the tree has previously been felled and a large stump is left quite close to the ground, the method differs slightly. A trestle is rigged up close to the stump, over which the pull rope is passed so that some lift may be given. A trench is cut under a few of the roots and a short rope passed through beneath them. Both ends of the root rope are then hooked to the end of the pull rope, the winch lever is worked as before and the stump hauled clean out of the ground.

The full hauling power can be exerted in any direction on all trees and stumps within a distance of 150 ft. from the anchorage, and an area of nearly 2½ acres stumped without shifting.

The speed and ease with which stumps can be extracted by this handy little plant are extraordinary. For example, an elm tree 60 ft. high was completely uprooted in ten minutes, which with hand labour would have occupied three men three days.

There is no more useful appliance in the forest than the monkey winch. It entirely hauls out stumps, can be used effectively for hauling logs out of difficult places, for hauling heavy pieces of machinery, for extricating tractors, etc., which may be bogged, and for a hundred and one emergency jobs. It requires little skill in manipulation, and what is necessary is easily acquired.

Drag Roads.

After felling the next item in timber operations is to get the logs out of the forest to the first assembly point, where they are converted into sawn lumber, or whence their transportation in quantity begins. The whole scheme of transportation should be carefully thought out and planned. No part of timber exploitation offers a greater element of profit and loss than handling and transport, while in any case the cost of transport is usually the largest item in the whole operation of logging.

In any form of dragging or ground hauling, roads must be cut through the forest from the scene of the logging operations to the skidway or first assembly point. These roads should radiate from the skidway as a centre to the back of the logging area. Such a road is not a made road in any sense of the word, but is merely a narrow strip cleared of stumps, brush, standing timber or any other obstruction. At the same time it must be remembered that the smoother and easier the road is made, especially for animal dragging, the greater will be the amount of timber hauled in a given time, and the less will be the strain on the animals and the less the wear and tear on the chains and other plant.

If the drag roads cannot be made straight, the curves ought to be as wide as possible and the inner side of each curve banked up with short poles to prevent the logs leaving the road when turning the corners. If the roads do not radiate from a centre but are cut parallel, they should be joined at frequent intervals by similar cross-roads, so that a cleared run is reached with a minimum amount of dragging from the stump. For animal dragging a track 6 or 8 ft. wide is sufficient. For a traction engine, tractor, and so on, the road must be wide enough to clear the dragging power. In swampy or soft places this road is corduroyed,

FIG. 33. OX TEAM HAULING LOGS IN AUSTRALIA.
[*By courtesy of Government of Victoria.*]

[*To face p.* 40.

FIG. 34. OXEN HAULING LOGS: NORTHERN CANADA.
[*By courtesy of C.P. Railway.*]

FIG. 35. SKIDDING LOGS BY HORSE HAUL: POLAND.

[*To face p.* 41.

that is, stout poles are laid close together, side by side, across the line of the road. If underneath the poles is laid a foundation of brushwood, the road will carry much better and last much longer.

Where the road is rough and the dragging difficult, logs of about 10 in. in diameter and 12 ft. long are placed zigzag across it and partly buried in the ground, each log with its neighbour forming an angle of about 60°. The logs can be placed across the road at right angles to it and 5 or 6 ft. apart for the same purpose, but this requires more timber, while the dragging is easier with the zigzagged logs.

Animal Dragging.

Oxen or buffalos may be used for dragging. They have the advantage over horses or mules in that they are easier fed in out of the way places, stand rougher treatment and do not sink so badly on swampy ground. They are also more docile and more easily managed in large teams. They are slower than horses and mules, but they haul heavy weights very steadily. They pull from the yoke, as shown in illustrations (Figs. 33 and 34). Horses and mules pull from the collar to a single tree on which is a ring (Fig. 35).

In hot countries especially, mules are more valuable than either horses or oxen, as they stand the heat better and can be worked harder. They stand rougher treatment and poorer feeding than horses and they are smarter and surer on rough ground. In dragging out a log a half-inch dragging chain about 12 ft. long is used to hitch the log to the draft. One end of the chain has an open hook. This end is passed round the forward end of the log to be dragged and the hook catches the chain, forming a running noose. The other end is hooked to the hauling power either by a single link or by a ring. When the pull commences the noose round the log is tightened and cannot slip. Logs are usually dragged butt end first. Any swollen butt or prominent excrescence is chopped off before dragging. Tongs which grip the end of the log may be used instead of a chain. They are made of 1½ inch diameter steel and are attached to the harness (Fig. 30).

For dragging down slopes where the log is apt to overrun the animals hauling, the form of grab in Fig. 30 is used, instead of a chain and hook. The grab hook is driven into the log near the butt end and the other hook is attached to the harness. If the log starts to run, the animals can be drawn aside and when the log comes opposite to them the grab hook will detach itself and the animals are freed.

When two or more logs are hauled in one drag, they are joined together end to end by couplers, either single or double, according to the weight to be dragged behind the first log (Fig 34). The hooks of these couplers are driven into the upper sides of the logs.

Dragging from the forest by animal power is the method least destructive to standing timber and young trees.

Mechanical Dragging.

Traction engines may be substituted for animal power in dragging, and if these are to be used the drag road must be cut correspondingly wide. The method of attachment of the logs to the tractor is the same as with animals, but naturally a much heavier weight can be dragged. The road therefore must be better, and any bridges, culverts, corduroy, and so on, must be built much more strongly. Dragging by traction engine is not now common. The wheels lose much of their power on sandy, loose, or wet soils and are practically useless on snow and ice.

On the other hand, tractors of the roadless type (Figs. 36 and 37) are eminently suitable for dragging in practically any kind of country and under any conditions.

Roadless tractors will work efficiently in swampy or wet ground and in places where animal power is impossible. They can readily travel over rough ground and stumps and other obstacles of considerable height, and the roads need no more preparation than for animals. They drag timber at approximately two to three times the speed of animals and drag heavier loads for longer distances and against grades that animals could not attempt. When not working they cost nothing to keep, while animals must

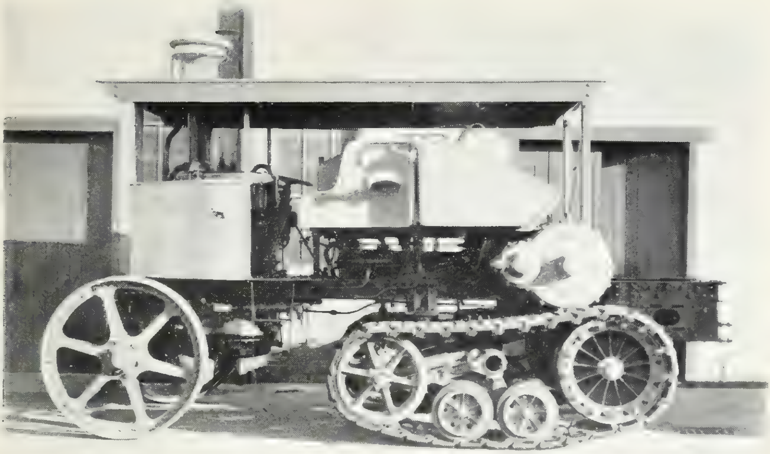

Fig. 36. Roadless Tractor.
[By courtesy of "Sentinel" Waggon Works, Ltd.]

Fig. 37. Roadless Tractor.
[By courtesy of "Sentinel," Waggon Works, Ltd.]

[To face p. 42.

be fed. Taken all round, this type of tractor is probably the most satisfactory means of skidding or log dragging. Over longer distances, large tractors are more economical than small ones, as the driving costs the same, while the power is much greater and heavier loads can be dragged.

CHAPTER V

LOG TRANSPORT.

Building skidways—Loading logs—Skidding—Sleds—Bummer—Janker—Timber wagon—Petrol and steam tractors and trailers.

THE situation of the logging area may be such that the logs may be dragged from the place they are felled to a railway or driving river, but it is more generally convenient to drag them out of the way as they are cut in the forest to a nearby collecting point on the fringe of the logging area, whence they are sent farther on by road, chute, flume, sled, log carriage, tram line or other suitable transport.

The first assembly point is the skidway. Here as the logs come in from the forest, they are stacked for convenient loading on to a sled or some kind of vehicle which will take a load. The type of skidway will depend on the method of further transportation, but the object is the systematic stacking of logs so that they can be rehandled without difficulty. If dumped down indiscriminately time will be lost in straightening them out for loading.

If the end of the drag is at a chute, flume or river, no stacking is usually necessary, and the method of handling in these cases will be described when these are dealt with.

Skidways.

If it is possible to bring the logging railway or tram line to the collecting point, logs need not be built up at all. A space about 50 ft. wide is cleared alongside the track on either one or both sides, this depending on whether logging is taking place on both sides of the track or not. The length of the cleared area will depend on the amount of storage required, but it should be 200 or 300 ft. to allow a number of cars to be loaded at once. If a large amount of timber is to be dealt with, a temporary platform is erected. A line of logs is laid alongside the track, and as near to it as will give ample clearance for a car with its load. A parallel line is laid about 10 ft. back, and another and another as far back as the storage extends. Logs are then placed across these at right angles, also about every 10 ft., all logs being slightly notched where they cross, to prevent slipping. Lines of logs are placed directly above the lower ones, and so on, till a platform has been built up high enough to reach what will be the top load of a car. The deck of the platform is composed of small poles to give footing to the men loading the cars, and skids are laid across these poles to the edge of the platform from the back. The cars are drawn up alongside the platform, and skids are placed reaching from the latter to the cars. Logs are dragged in from the forest to the back of the skidway parallel to the track, rolled over the skids and on to the cars, or, if these are not at hand, are left on the skids in readiness for loading. They need not be stored to any great height, as it is easier and cheaper to clear additional ground and store logs as nearly on the level as may be. After all the logs have been brought in and retransported, those forming the platform are taken up and carried away likewise.

Whatever the type of skidway, it is essential that the logs be brought in parallel with the track or road by which they are taken away.

Instead of storing logs and building a platform, all logs may be loaded as they come in directly on to cars by means of crosshaul worked by either animal or mechanical power. Skids are placed from the ground to the car deck at the side the logs arrive. As a log is brought in, it is placed at the lower end of the skids parallel to the car, a light hauling chain is hooked on to the car, passed under and over the log and the end carried back across the car and the track, and hitched on to the animal or mechanical power. When the pull is given, the log is rolled up by the chain on to the car. When animal power is used for the crosshaul, a space must be cleared on the other side of the track from the loading berth long enough to give the animal room to haul in the length of the chain. Or, by an arrangement on any handy stumps or trees, of blocks through which the hauling chain passes, the pull can be made in any direction.

If the logs are to be stacked meantime, and taken from the skidway by means of sleds or timber waggons, they are built up at different spots along a pre-determined road, convenient for the drag from the forest. The ideal condition is, of course, a slightly downhill dragroad from the forest to the skidway, and the road from this point for either sled or wheels also slightly on the down grade, so as to give an easy start with the load. A load should never start uphill, and if a natural downward slope is unobtainable, the loading berth should be built up so as to give at least a down grade start.

In building a skidway of this type, the head block is first laid down. This is a log about 15 ft. long and about 2 ft. in diameter. It is placed on the ground parallel with the road and 4 or 5 ft. back from it. Two deep notches are made on the top about 10 ft. apart. In these notches the skids are placed, these being logs a foot or more in diameter and as long and straight as can be obtained, as they form the base on which the decks of logs are built up. The front ends of the skids are spiked to the head block and the back ends slightly sunk in the ground, giving a gentle slope from the latter to the top of the headblock.

A notch is made on the top of each skid over the head block, and a chock placed in it to prevent the first log rolling right over the end. If very long logs are to be stacked, the head block can be correspondingly long and more skids used, placing these 8 ft. or so apart.

Skidding.

When the first log is brought in, it is dragged parallel with the head block at the bottom end of the skids. A light hauling chain with a hook on one end is now passed, hook end first, over and under the middle of the log, and is carried back and hooked to a sling on the middle of the head block. The free end is made fast to the hauling power and when the pull is given, the log rolls up the skids till it brings up against the chocks.

FIG. 38. LOADING LOGS ON SLED: ONTARIO.

[*By courtesy of Canadian Government.*]

[*To face p.* 46

Fig. 39. Unloading Logs from Sled: Ontario.
[*By courtesy of Canadian Government.*]

[*To face p.* 47.

The haul may be either direct, or diverted by means of blocks as before described. Subsequent logs are dealt with in the same manner, being rolled till they are stopped by the previous ones.

After the bottom row is completed, light skids are laid across it reaching from the back to the log short of the head block. The next deck of logs is rolled across these skids till each log rests in the hollows between those underneath, the skids being withdrawn a little when each log reaches its bed. In this way logs can be stored as high as necessary. A man at each end of the log being hauled up keeps it going straight. In emptying the skidway, the sled or car is drawn up in front of it, and the logs slid down to it on a couple of skids.

If logs have to be dragged up to a skidroad out of a deep hole with sides too steep for animals to keep their footing, and the amount to be recovered is not enough to justify putting up any power plant for the purpose, a simple vertical windlass can be rigged up at the top of the hill with a long horizontal arm. A wire rope attached to the drum of the windlass is taken down by hand and hitched on to the felled trees. The animals' hauling gear is now attached to the arm of the windlass, and when the animals are driven round in a circle, the drum revolves, the wire rope is wound in and the tree hauled up to the top.

An alternative plan is to use the monkey winch described in the previous chapter.

Sleds.

Instead of dragging the logs from the forest to the skidway, it may be more convenient to haul them on sleds. These are of various kinds and, while of course particularly adapted to hauling on snow or ice, are helpful in many other conditions as well, especially on soft, mossy land, and some types may be used in most woods.

The simplest has no runners, but is built of heavy planks 6 ft. long and with a total width of 3 ft. The planks are turned up at the front end so as to slide easily, and securely fastened together by means of cross pieces bolted to the bottom. About the middle of the sled is a bunk, a cross piece of timber 6 in. square, bolted to the bottom. One end of the log to be dragged is laid on the bunk and chained to it and the other end drags on the ground. The sled is hauled by drag chains passing through holes in the turned up front ends of the bottom planks and hooked to the ends of the bunk.

Another kind for hauling short logs free of the ground is about 4 ft. wide. It has two runners, each 12 ft. long by 6 in. high and 4 in. thick, and is shod along the bottom with iron. A bunk of 8 in. square timber is bolted across from runner to runner about 3 ft. from each end. Runners for sleds must be made from timber having a natural bend, so that the curved end of the runner has the grain running with it, when it can simply be hewed into its final shape. If it is sawn into shape diagonally across the grain, it will not stand any usage (see Figs. 38 and 39).

A handy little sled for dragging logs in the woods at all seasons is built of two hardwood runners each about 6 ft. long, 6 in. high and 4 in. thick, which need not be shod, as the sled is usually made in camp. A 6 in. square bunk is fastened across from runner to runner a couple of feet from the after end of the sled. The fastening has only one bolt at each end, as the sled is intended to be loosely made. At the forward end a stretcher is fastened from runner to runner on the inside of the runners. A sled of this kind, where the runners work partly independently, is more easily handled on rough ground than if the sled were stiff, as the one runner is often free and starts when the other sticks, and the impetus given will start the whole sled with its load.

A ring is bolted to the middle of the bunk on the top, and from these the chains pass which make the logs fast to the sled for dragging. One end of the log is on the bunk, the other drags on the ground. A short dragging chain is fastened to each end of the bunk. These chains meet in a ring in front of the stretcher, and to this ring is hooked the drag chain of the animals' harness.

Adaptations of these sleds can be made to suit local conditions.

Wheels.

Where the nature of the ground makes any kind of sled hauling unsuitable, wheeled vehicles of various descriptions may often be usefully employed, instead of dragging the logs.

Bummer.

A handy form of vehicle, when the bottom is good and the ground is fairly clear, is the bummer, a low two-wheeled log

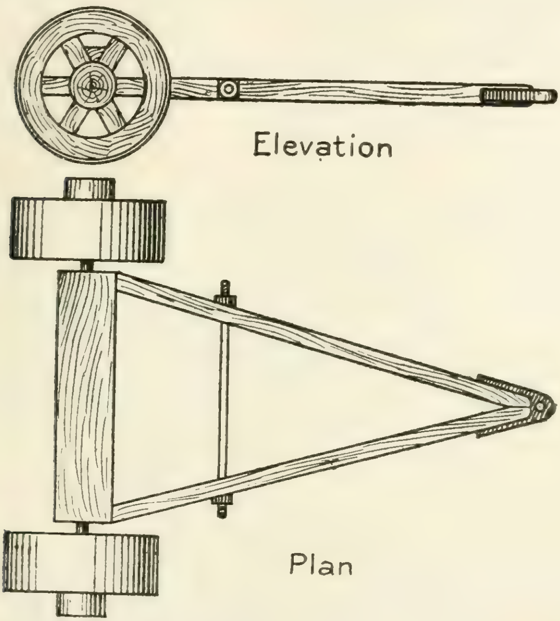

FIG. 40. BUMMER. Scale $\frac{3}{8}$ in. = 1 ft

carriage. The wheels are 2 ft. in diameter with a face of 6 in., although they may be home-made of solid hardwood with a face of 1 ft. The axle should be of about 3 in. square steel. On the axle is a wooden bunk 3 to 4 ft. long and 6 in. square, slightly concave on the top, so that the log will lie in the middle of the bunk. A triangular drawbar about 6 ft. long is firmly bolted to the axle, the apex of the triangle being the forward end. This drawbar is both the lever for lifting the log and the attachment for hauling after the log is in place. A pair of tongs is attached to the front of the bunk for the purpose of making fast the log to the bummer for transport. The bummer is backed to the log about 4 ft. from one end, the drawbar raised to the perpendicular and the bunk with the tongs lowered against the log, when the tongs are gripped into it. The hauling team now pulls on the raised end of the drawbar, which first of all brings it to the horizontal, at the same time raising one end of the log from the ground. The bummer is then turned until the log drops between the wheels on to the bunk, and the load is ready for hauling. When unloading, the tongs are disengaged from the log and the bummer hauled out from under it (Fig. 40).

Janker.

Where the ground is covered with brush or scrub or fallen timber, the bummer is not used and is replaced by the janker, or log carriage. The janker has a pair of wheels of diameter up to 12 ft. or even more. The axle is cambered so as to allow the carriage of logs of very large diameter. A long pole is fitted to the top of the camber of the axle and a strong hook fitted on the after end of the pole. The janker will carry very long logs instead of these being cross-cut into shorter lengths. The method of operation is as follows: The janker is backed over the log, the latter lying long ways between the wheels. A chain sling is put round the log at a distance from the after end, which will balance it easily when lifted. The front of the pole is then raised till the hook at the after end is low enough to catch on to the chain sling. The pole is then lowered by the team pulling on the end, when the leverage raises the log from the ground. The front end of the log is then made fast to the pole and the latter hitched to the team. A janker with high wheels needs practically no roads made for it in the forest. It will travel easily through brush and over low stumps and fallen timber. It is not advisable to haul it down any steep incline, as it may run away and overhaul and injure the team. If any steep places

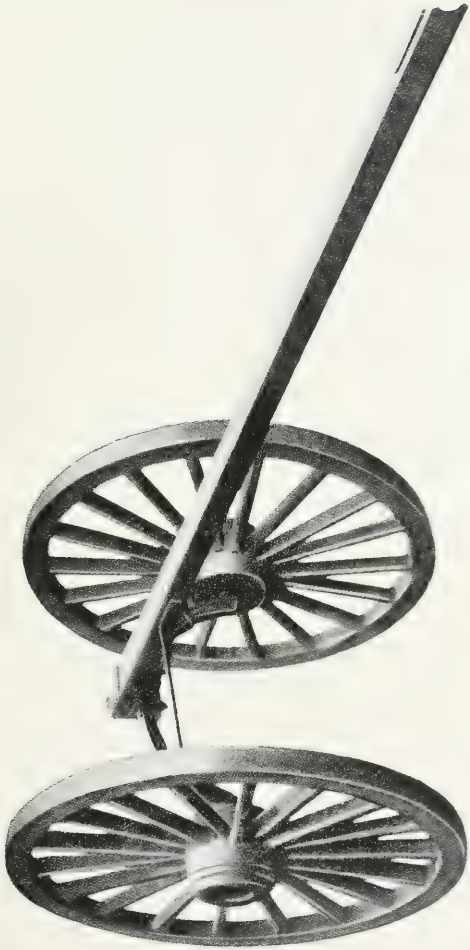

FIG. 41. TIMBER JANKER.
[*By courtesy of T. D. & W. Dales, Ltd.*]

[*To face p.* 50.

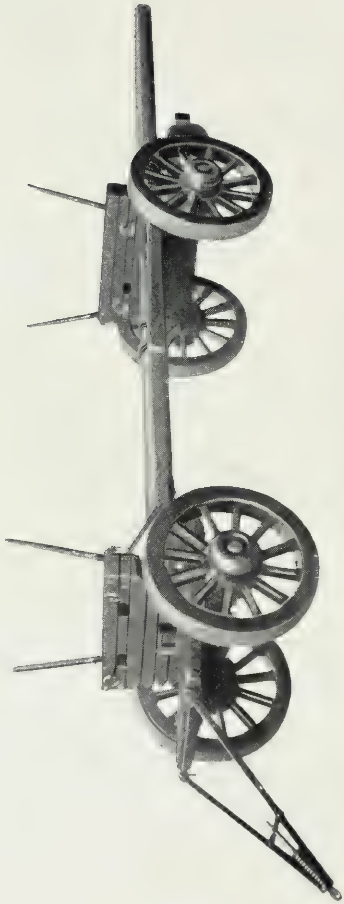

FIG. 42. TIMBER WAGGON.
[By courtesy of T. D. & W. Dales, Ltd.]

[To face p. 51.

must be negotiated, a long stout rope can be made fast to the back of the janker. This rope should be given two or three turns round a tree or stump at the top of the slope and gradually eased, thus acting as a sufficient brake to prevent a runaway. Several logs can be bound together with chains and carried on the janker at one time (Fig. 41).

Waggon.

The timber waggon (Fig. 42) is another type of vehicle for the carriage of logs. It can be used directly in the forest where the standing timber is not too close, or it can be conveniently loaded from the skidway. In the former case it will be loaded from the ground by a cross-haul, two skids being placed slanting from the ground up to the top of the waggon, the logs being cross-hauled up the skids. This is illustrated in Fig. 43, where a "Sentinel" steam waggon is shown cross-hauling a log by the winch which forms part of these tractors. When the bottom tier of logs is loaded, the ends of the skids are placed on these logs and another deck piled up until the load is complete.

The type of waggon can be seen in the illustration just mentioned. It has two heavy bunks over the axles on which the logs rest. The back bunk should have spikes on the top with the sharpened ends upwards to prevent the logs slipping on a steep down-grade hill. It has a heavy brake on the back wheels.

The janker is usually hauled by animals—horses, mules, or oxen. The timber waggon can also be hauled by animal power, but is more suitable for traction engine or tractor. In these cases, instead of being fitted with shafts or pole for harnessing the animals to, it is fitted with a triangular drawbar, which can be seen in the illustration with the front end resting on the ground.

Tractors.

Instead of timber waggons, motor tractors can often be used for the entire haul from the forest to the mill, in cases where the quantity of standing timber or the size of the timber does not make a forest railway a paying proposition.

A road requires to be made for motor traction, and its character will depend on the load it will be expected to carry in any weather, and the total quantity of timber to be hauled over it. Petrol driven tractors are employed extensively (see Fig. 47).

A steam driven tractor, the "Sentinel," has rubber tyres and two-speed gear, and, an immense advantage, is furnished with a full power winch driven by a heavy chain from the intermediate gear shaft, thus operating at two different speeds and powers. It can reach any country at all accessible, and the winch will drag logs of 5 tons up out of the steepest valleys. It will haul two trailers, and an example of its hauling capacity is seen in one case where it daily hauled a load of twenty tons a distance of twelve miles to the sawmill, on unfavourable roads with a gradient in places as steep as 1 in 6, the round trip taking a little over two hours, and being carried out daily, summer and winter. The fuel, water and oil consumption is low. If a tractor like the "Sentinel" is used, logs can be hauled by the winch from where they are felled to the trailer, and then loaded by a cross-haul, also operated by the winch. The "Sentinel" steam waggon described is shown in operation in Figs. 44 to 46.

At the unloading berth one side of the road should be elevated about a couple of feet higher than the other side. The logs will then roll off of themselves when the chains or other fastenings are removed.

Plank Roads.

In soft or specially bad bits of country, plank roads are made to carry the tractor and trailers. These need not be the whole width of the tractor, but may have one road laid for each wheel. Each carrying surface is a stringer 6 in. thick and about 30 in. wide, made up of two or more pieces. Sleepers to carry the stringers are sunk in the ground every 30 in. and the stringers are securely spiked to these, the stringers resting on the ground as well as on the sleepers. On steep grades the sleepers are placed lengthwise, and the carrying planks crosswise on them and about an inch apart. This method of laying prevents the wheels skidding on a wet grade.

Fig. 43. Steam Waggon Loading Log by Crosshaul.
[By courtesy of "Sentinel" Waggon Works, Ltd.]

Fig. 44. Steam Waggon's Winch Dragging Log out of Hollow.
[By courtesy of "Sentinel" Waggon Works, Ltd.]

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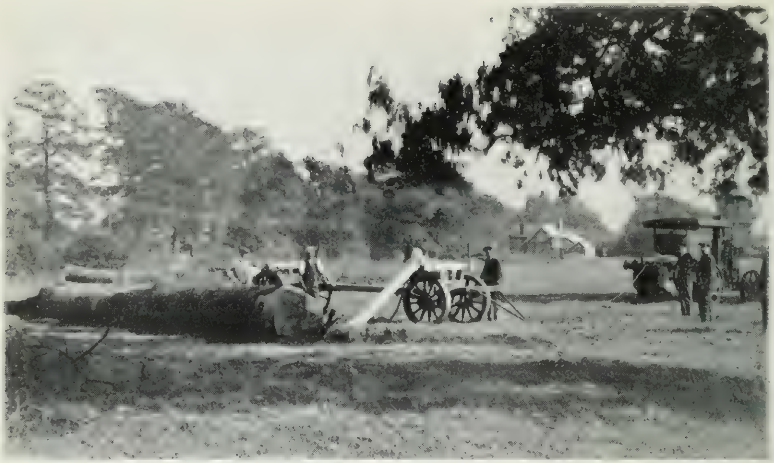

FIG. 45. CROSSHAULING LOG: LOADING BY SKID ON TIMBER WAGGON.

[By courtesy of "Sentinel" Waggon Works, Ltd.]

FIG. 46. LOADING LOGS ON TIMBER WAGGON.

[By courtesy of "Sentinel" Waggon Works, Ltd.]

[To face next Plate.

FIG. 47. MOTOR TIMBER CARRIAGE WITH DOUGLAS FIR IN FOREST: BRITISH COLUMBIA.

[By courtesy of Canadian Government.]

[To face last plate

Guard rails made from poles 4 in. in diameter are spiked to the inside of each track and to the sleepers as well, and braced at intervals by smaller poles stretching from one to the other. At curves, similar guard rails are spiked to the outside of the tracks as well.

A road of this kind must be drained and no water must be allowed to lie on the track. Ditches are cut on each side of the road, with cross ditches from one to the other to carry off any possible water.

CHAPTER VI

WIRE ROPE OPERATIONS

Wire rope haulage—Ground haulage—High lead ground skidding—High lead overhead skidding—Swamp skidding—Aerial tramways.

Skidding or dragging in logs from the forest by means of wire rope haulage can be done by different methods. It may be carried out by making a rough pole road, laid on a track cut through the forest, and hauling the logs along it by means of a donkey engine and winch.

A much more rapid and powerful method is by what is known as the high lead system, which may be either ground skidding or overhead skidding. Ground skidding is suitable if the country is fairly level and free from boulders and other obstacles, deep gullies and heavy undergrowth. It is particularly suitable when the timber is big and the stand a thick one. For ground skidding, heavy tops and slash must not be left on the ground in the way of the dragging or the logs will be hung up and much unnecessary delay and expense caused in operating.

High Lead.

There are various systems of both ground and overhead skidding, but only one is described here, the Lidgerwood system, over which no other system seems to have any advantage, while it has distinct advantages of its own, such as the slack-pulling, which will be described later.

Ground Skidding.

In ground skidding, two or four skid or dragging lines of wire rope are used and are returned by animal haul from the skidder to the logs waiting to be brought in. As this form of dragging is only to be employed in fairly easy country, it is best and cheapest to use animals to haul the

FIG. 48. HIGH LEAD GROUND SKIDDING

[*By courtesy of Messrs. Lidgerwood.*]

[*To face p.* 54.

FIG 49. TOPPING SPAR TREE FOR HIGH LEAD: BRITISH COLUMBIA.
[*By courtesy of British Columbia Government.*]

[*To face p.* 55.

free rope back again from the skidder. However, if desired, half the lines in use can be fixed up as rehauls and the skidder will haul the empty rope out. This is done by having a block on a tree or stump at the end of the haul through which the rehaul is passed. When the engine winds in the rehaul, the hauling rope goes out and *vice versa.* With this mechanical rehaul, the ropes can only be taken in a straight line in one direction, and the block has to be shifted every time the area then reached is cleared of logs, while only one-half of the power of the skidder is in use at a time. With animal rehaul all the skidding lines are in use at once bringing in logs, and they can be taken in any direction to wherever logs may be waiting for them. The full man, animal, and mechanical power is thus constantly in operation and there is no waste time. (See illustration, Fig. 48). The skidder itself is an engine, as shown in the illustration, with a number of drums according to the number of hauling lines it operates. It can also be adapted to loading logs as it brings them in directly on to railway or road waggons, etc., instead of the logs being built up on a skidway. Or the loading appliance can be used to stack the logs if necessary till means of further conveyance are at hand.

The skidders are supplied by the makers with skidding and loading beams of steel, but these make the plant very heavy and difficult or impossible to bring into many situations in the forest, and it will always be possible to get some standing tree to use as a mast on which to fix the blocks through which all the ropes run.

If a large stretch of forest is to be logged, a road must be made through it along which the skidder is brought. Probably a forest railway may be built on this line and the skidder railed to its place. Along the cleared way a number of convenient trees are selected before the felling begins which are to act as spars for skidding. These trees should be at intervals of about 1,000 ft., and each one should stand back from the track about 10 ft., so as to give room for loading on cars or waggons. Each spar must be a straight and sound tree, not less than 18 in. in diameter at 60 ft. above ground.

Topping.

The tree is topped to take off the topheaviness of its crown and give rigidity to the stem when the strain of hauling the log is on it (Fig. 49). The rigger, with axe or saw, climbs the tree by means of climbing irons. He also has a rope belt encircling both himself and tree to assist him in climbing and to keep him in position when cutting through the tree at the top. This rope belt should have a steel core running through it to prevent the rigger chopping it through as well as the tree and so bringing himself to the ground. At a suitable height he chops or saws through the stem, and the top falls, leaving a straight, clean spar. This is strongly guyed by a number of strong steel guy ropes fastened to convenient stumps. The guy is fastened at the proper height by means of a thimble and shackle, and the lower ends are tightened up by the engine. The whole of the rigging is clearly seen in illustration Fig. 50.

The rigger first fixes up on the top of the spar a small block carrying a light line, the rigger's line, for hoisting into place all the rest of the apparatus. The blocks for carrying the drag ropes, two to four as the case may be, are 17 in. and are hoisted as far up the spar as possible and hung to it by means of strong chains. The hanging parts of these chains to which the blocks are attached are left long so as to give sufficient play for the block to swing round the spar and so allow the whole area in a circle round the tree to be logged without shifting any part of the plant.

One of the guys which cross the track is used as a loading cable. It supports a loading carriage, which is held in place by a stay rope. From this carriage is suspended an 11 in. block for the hoist line to run through. Another 11 in. block, the hoist rope block, is hung under the lowest dragging line block by a rigging chain in the same way. The stay rope block is a lighter block hung below the hoist rope block. The loading carriage is seen in Fig. 56.

The ropes, of 1 in. to $1\frac{3}{4}$ in. diameter, from the drums of the skidding engine are now led up through their respective

Fig. 50. High Lead Ground Skidding: Head Spar.

[By courtesy of Messrs. Lidgerwood.]

[To face p. 56.

blocks and the free ends are hauled out by animals to the logs to be dragged in. The hoist rope is similarly led from the loading drum through its block on the spar, then through the loading carriage and down to the track, where loading tongs are fastened to the free end by thimble and shackle. The stay rope is then tightened up and made fast, and the whole plant is ready for dragging in logs and loading or stacking them as they come in.

The first spar will have been the farthest out, so as to clear the outside of the area first. When this has been logged and loaded, the plant is shifted back to the next tree, the same operations are gone through again, and so on till the whole area has been cleared.

Overhead Skidding.

If the country is much cut up by deep gullies or valleys, or swampy places have to be crossed, or if there is dense and heavy undergrowth, or the country is steep and mountainous or rocky, or, in short, if the topography or some other condition makes ground hauling difficult, costly, or impossible, the high lead overhead skidding is the method to be employed. The logs or ends of logs being transported through the air, skidding is practically independent of ground conditions. Rocks, cliffs, gorges, fallen timber and so on offer no difficulties. A dozen small logs can be handled at one trip or one large one. Trimming the butts or otherwise preparing the logs for dragging is unnecessary. Logs are delivered free from sand or grit, avoiding the usual cause of damage to saws at the mill. In the Lidgerwood system all blocks and wire ropes are operated clear of the ground, consequently the cost of repairs is kept at a minimum. Another advantage is that skidding downhill is absolutely safe. If any of the ropes break the load drops to the ground.

In rigging the overhead system, the procedure is partly on the same lines as that which has just been described. Head spars are chosen along the track and topped in the same way as the ground skidding spar. In the case of the overhead system, however, each head spar has a number of tail spars associated with it on which to rest the outer end of an overhead carrying cable.

The average distance of the tail spar from the head spar for convenient working is about 750 ft. This, however, partly depends on the nature of the country and may be as much as 1,500 ft. In mountainous country where a much greater sag on the carrying cable is attainable, a distance of 4,000 to 5,000 ft. has been successfully worked.

The group of tail spars for one head spar should be selected and marked before felling begins, and they should be round the segment of a circle with the head spar as centre at a distance from each other of from 150 to 200 ft., and as nearly as possible with the same radius. This latter makes for quick changing of the gear from one tail tree to another as each run is logged, with practically no stop in the work.

The head trees must be as described for ground skidding, while the tail trees must be equally straight, clean and sound, and not less than about 2 ft. in diameter at 30 ft. from the ground. They are topped as before.

In rigging the plant, a temporary block is placed on the tail spar at the height the main cable is to be fastened, this depending on the nature of the ground to be traversed, but high enough, allowing for the sag, for the logs to clear all obstacles. A light line, the changing line, is run out from the engine through the tail spar block and back to the head spar where it is attached to the main cable, a wire rope of $1\frac{1}{4}$ to $1\frac{1}{2}$ in. diameter. The engine then hauls in the free end of the changing line, thus hauling out the main cable. This is given a turn round the tail spar at the height decided on and then made fast to a stump or tree on the far side from the head spar, thus serving as a guy. An additional wire guy rope is also made fast to the tail spar and similarly tightened up to a stump. The head spar is strongly guyed by wire ropes, six guy ropes near the top and three near the middle being used. The main cable is run through the skidder carriage, the home end of this cable ending short of the head spar in a block fastened to it by means of a thimble and shackle. The rigging of the head spar is shown in Fig. 51. A cable extension piece ending on the tail spar side in a heel block passes through a saddle block made fast to the head spar at the ultimate height of the main cable. This extension piece ends on the side away from the tail spar in a split anchorage. The block on the inner side of the main cable and the heel block on the extension piece are now connected by a block and fall tackle, and after the anchorage is made fast, the

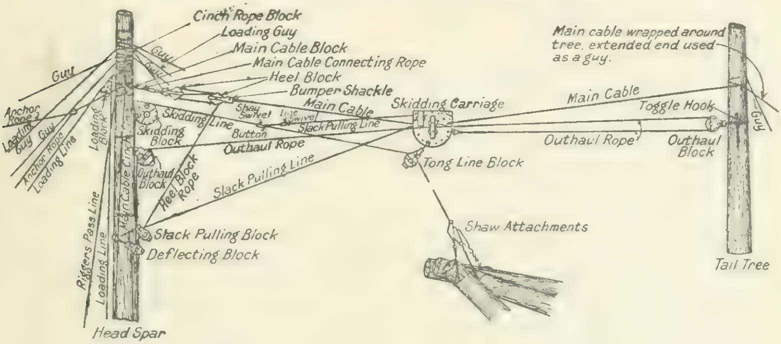

FIG. 51. HIGH LEAD SKIDDING: RIGGING OF SPARS.

[*By courtesy of Messrs. Lidgerwood.*]

slack of this is taken up by the engine and the main cable thus pulled up to its proper sag.

The skidding line block is then made fast to the head spar directly under the cable extension piece, by means of a 2 in. plough steel strap wound two or three times round the tree. Immediately below this is the outhaul block similarly fastened. Below that again is the slack-hauling block, and below it a deflecting block for taking the fall from the heel block rope connecting the main cable with the extension piece.

The outhaul block has meantime been made fast to the tail spar below the main cable. The outhaul line of $\frac{3}{4}$ in. rope is now passed through its block at the head spar, run out and passed through the tail spar block, brought back and made fast to the carriage. The skidding line is then passed through its block on the head spar and through the tong line block suspended from the carriage, and is ready for its share in the operation. The $\frac{3}{8}$ in. slack-pulling line is now passed through its block, run out and passed through its sheave on the carriage, and brought back and fastened to the skidding line at whatever point in it between the carriage and the head spar is necessary to give the proper reach to the working of the skidding line. A small block is fastened to the head spar above the main extension piece. This carries the main cable cinch line which is attached to the extension piece at the heel block and assists in tightening up.

The loading guy line is now rigged, spanning the track or road as in the ground skidder, and the whole plant is in readiness for skidding and loading.

In working the plant, the outhaul rope draws the carriage out along the main cable. When it reaches the place the logs are to be attached, the outhaul drum is thrown out of gear and braked, and the carriage is held. The slack-pulling rope continues pulling on the skidding line, and hauls the latter along till the free end easily reaches the slingers who are waiting to attach the logs. While the carriage has been away with the previous load and is coming back, the slingers have been putting chain slings on the logs to be hauled. Short chain or wire rope slings are placed on the smaller end of each log, and these are not attached direct to the skidding line but to a bunch line, a wire rope about 40 ft. long. The ends of the slings are gathered up by one end of the bunch line, while the other end is attached to a swivel hook on the end of the skidding line. (See illustration, Fig. 52). The swivel allows the load to twist about without fouling the skidding line. Three bunch lines are in use at once—one being detached at the head spar, one being attached to the logs by the slingers, and one travelling back to the slingers from the head spar. Thus there is no waste time.

When the signal has been given that attachment has been made, the skidding drum is put in gear, hauling in the skidding line with the bunch line attached. The latter pulls the logs together, making one bunch, and the front end of the bunch is lifted up well clear of the ground, thus

FIG. 52. HIGH LEAD OVERHEAD SKIDDING: THE BUNCHING LINE.
[*By courtesy of Messrs. Lidgerwood.*]

[*To face p.* 60.

FIG. 53. HIGH LEAD OVERHEAD SKIDDING: UNITED STATES.
[By courtesy of Messrs. Lidgerwood.]

[To face next plate.

FIG. 54. HIGH LEAD OVERHEAD SKIDDING: U.S.A.
[*By courtesy of Messrs. Lidgerwood.*]

[*To face last plate.*

Fig. 55. Overhead Skidding: Logs Arriving at Headspar: British Columbia.

[*By courtesy of British Columbia Government.*]

FIG. 56. HIGH LEAD OVERHEAD SKIDDING.
[By courtesy of British Columbia Government.]

[To face p. 61.

clear of obstruction. When they are high enough, the skidding line hauls them to the head spar. (See illustrations, Figs. 53, 54, 55 and 56).

As soon as it starts, the slingers place the slings and bunch line for the next load and have it ready by the time the carriage comes back with the empty bunch line and slings. As will be seen from the illustration, the bunch line can be laid in and out any standing stumps, so that when the pull comes the stumps do not foul the logs.

The slack-pulling line obviates the necessity of hauling in the skidding line by hand so as to reach logs lying away to one side or the other of the main cable. The slack-pulling line is also an advantage when the skidding line has to be lowered into a deep pothole.

When the load arrives at the head spar the bunch line is at once unhooked, an empty line and slings hooked on, and the carriage returns at full speed to the slingers. While it is away, the guy loading line is first hooked on to the bunch rope and the logs hauled by one end to the track. This straightens them out, makes handling easier, and places them convenient for loading up. The slings are now taken off, and with the bunch lines are ready for the next trip of the carriage.

Where loading cannot be done at once, the loader stacks the logs by the side of the track. If they can be loaded at once, however, it saves double handling and extra expense and lessens the risk of damage by fire or insects. If loading should be done on to a railway, no locomotive is necessary to move and place the waggons, as this can be done with one of the ropes from the skidder.

The slack-pulling line is attached to the skidding line by a sliding swivel at any desired point, this depending on how much free end of the skidding line is wanted to reach the logs. Buttons are clamped to the skidding line to keep the swivel in its place.

Changing.

There are two methods of changing the main cable from a run that has just been logged to the next run. In one method, two main cables are employed, but this is only suitable if the country is fairly level and not much broken up by deep gullies. While one run is being logged, the main cable on the next run is being put in place by the riggers in the same way as the first. When all the logs on the run have been hauled, the cable is dropped and disconnected from the head spar heel block and left on the ground. The next cable is run through the carriage, made fast to its tail spar and tightened up. Meanwhile a light changing line is run from the engine round the third selected tail tree and attached to the tail end of the first cable. The engine then hauls in the changing line until the end of the main

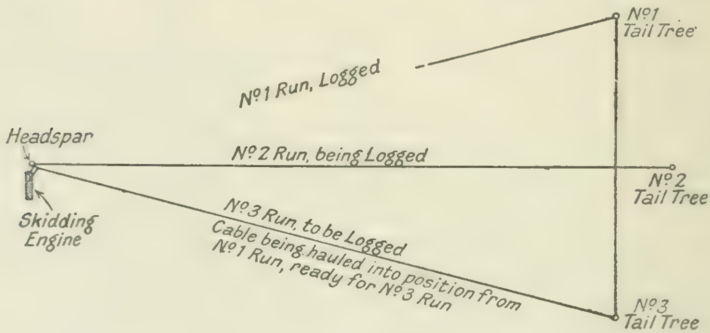

FIG. 57. PLAN OF CHANGING RUNS IN HIGH LEAD SKIDDING.

cable reaches it. The main cable is now lying on the ground, stretched from the head spar to the third tail tree. Each change reverses the ends of the cable. Changing only requires about a quarter of an hour, so there is practically no stoppage of operations (Fig. 57).

By the other method only one main cable is used. While one run is being logged, the riggers run the changing line out from the engine through a block on the next tail tree and back to the engine. When the first run has been logged, the cable is dropped from the tail tree and wound in on the engine. The end is then attached to the changing line, the engine started and the cable run out and made fast to the next tail tree. The reel engine gives the proper tension and stores extra length of cable.

By the High Lead System, logs can be hauled in from behind the tail tree. By the Lidgerwood System they can also be hauled downhill, uphill, or out of a deep valley. They can also be hauled up out of one valley, over a hill and down into the bottom of another valley, by having on the top of the divide an intermediate spar tree which carries the main cable. Logs are skidded up and stacked on the top. The carriage is then shifted over to the home side of the intermediate spar and the logs are skidded down to the head spar. There is a patent carriage on the market which runs past the support on the intermediate tree and does away with the necessity for relaying.

In mountainous country where the plant can run as much as 2,000 ft. and over, an area of 200 acres can be skidded from one setting, if the logging radiates entirely round the head spar. With such plant as has been described, the empty carriage runs out at a speed of 2,000 ft. per minute and brings logs home at a speed of 700 ft. per minute.

Pole Road and Winch.

If for any reason it is not desired to use the High Lead System and if the ground is fairly level and easy, and the logs should be hauled out on the ground by a wire rope from a winch and donkey engine, it is necessary to lay down a pole road along which to drag the logs, the latter being skidded to the pole road by animal or other subsidiary means of haulage. The pole road would be constructed in the same way as the timberslide or chute described in the next chapter, only on level ground. It should be as straight as possible, as while perpendicular rollers can be placed at the inner side of any curves to keep the rope in place as much as possible, still the logs are apt to jump the road, and replacing them means additional labour and expense.

Swamp Logging.

For power skidding in swamps a different method of ground skidding is used. The skidder is either mounted on wooden skids or runners and pulls itself about in the swamps by its own power, or it is mounted on a scow or barge. If the latter, canals are dredged through the swamp of sufficient width and depth to allow the scow free passage. It is then towed up the canal and brought to an anchorage at a suitable place for logging at the far end of the canal, and runs through the swamp are cut for a distance usually of 3,000 or 4,000 ft., radiating all round the scow as a centre.

A series of tail trees has previously been selected at the far ends of the intended runs about 150 ft. apart, round the segment of the circle. The runs must be well cleared out and stumped, so that the logs will haul easily.

When the timber is felled, the forward end of each log is "sniped," that is, trimmed so that it will run easily. Two 2 in. holes are bored opposite each other a foot from the forward end of the log. In these holes are inserted the puppets of the dragging chain, which is attached to the main hauling rope, as shown in Fig. 58. The method of fastening by puppets is the only satisfactory one in this form of operation. The illustration shows the shackles on the main hauling cable. There are four of these at intervals at the outer end of the cable, so that four logs can be hauled in at one time. The lighter outhaul rope is also shown.

In logging a run, a sheave block is made fast to the tail tree about ground level. A light wire rope changing line is run out from a drum on the skidder through the sheave and back to the skidder. The free end of the outhaul line is then made fast to the hauling cable, the outhaul end reeled up, and the hauling cable pulled out to the tail tree. Logs are made fast to the shackles on the hauling cable, and the latter wound up on the skidder drum. When it comes in and the logs are detached, the outhaul line is again wound in, and the hauling cable pulled out to whatever part of the run has logs in readiness.

When one run is logged, cables are wound in, the sheave block fastened to the next tail tree, and the process repeated until the whole area within reach has been cleared, when the setting of the skidder is changed.

Steel cones are sometimes placed over the forward ends of the logs to enable these to slip round or over any obstruction and thus avoid being hung up, but they are heavy and awkward to handle.

Logs can be hauled as much as a mile by this method, but the longer the distance the greater the wear and tear on the ropes.

The illustration in Fig. 59 shows this operation and also shows the steel cones.

Where swamp logging is necessary and the amount of timber does not justify the dredging of canals and other heavy preparatory work, stands may be logged by a gasoline skidder. This is shown in illustration Fig. 60. It is fitted on wooden skids and pulls itself about in the swamp

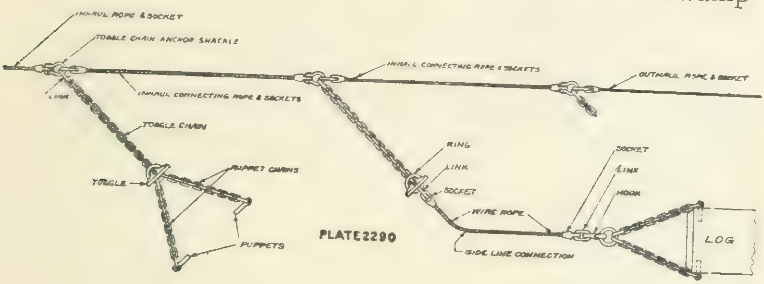

FIG. 58. LOG ATTACHMENTS FOR SWAMP LOGGING.

by its own power from one setting to another. When it is desired to move it, a wire rope from one of the drums is pulled out and made fast to a tree or stump in the direction the skidder is intended to travel in. When the rope is wound in on the drum, the skidder pulls itself up to its new stand. It will skid logs for 1,800 ft. and gather them up into different collecting places, whence they can be picked up for further transportation. This skidder can be taken where the heavy steam plant is impossible. It will work steadily all the year round on a consumption of $1\frac{1}{2}$ gallons of gasoline per hour.

Ropeways.

Ropeways or aerial tramways may be satisfactorily used in rough or mountainous country to bring logs or sawn timber from a high to a low level down precipitous slopes, or across rivers or deep gorges. They have the advantage that little preparation or construction is necessary, they can negotiate practically any gradient, and they can be constructed in practically any kind of country. The carrying rope is carried on trestles which must be high enough for the load everywhere to clear the ground and any obstructions.

There are two general types of ropeways. One has a fixed carrying cable made fast to or resting on spars in the same way as the Lidgerwood Overhead Skidding plant already described. On this a single carriage runs, and if this is the kind adopted there is no particular advantage in putting up anything but the plant referred to.

If there is a downgrade with the load all the way, the load can run down by its own weight. A light rope would be attached to the carriage for its backhaul by a winding engine.

If two fixed carrying ropes are erected side by side on a constant downgrade, two carriages could be used. A light wire rope would connect the two, the length of the rope being such that when one carriage was at the loading terminal the other would be at the unloading one. If the connecting rope is passed two or three times round a drum at the top terminal furnished with a band brake, no power would be necessary, as the loaded carriage going down would haul the empty one up, and the speed would be regulated by the brakesman. The carriages are hung from the carrying rope on two small deeply grooved wheels set tandem.

In the other type the carrying cable is an endless one travelling at a speed of about four miles per hour. At each terminal is erected a staging, at the outer end of which is a large horizontal wheel with a grooved rim round which the cable revolves. At the beginning of the staging where the rope revolves, a shunt rail is fixed a few inches above the rope. The carriages are clamped to the moving cable at intervals as they are loaded. The frame of the carriage is extended above the cable and ends in two small grooved wheels set tandem. When the loaded carriage arrives at the staging,

FIG. 59. SWAMP LOGGING: SOUTHERN UNITED STATES.

[By courtesy of Messrs. Lidgerwood.]

[*To face p.* 66.

FIG. 60. GASOLINE SWAMP SKIDDING ENGINE: U.S.A.

[By courtesy of Messrs. Lidgerwood.]

[To face next plate.

FIG. 61. AERIAL ROPEWAY: A TRESTLE AND CARRIAGE.
[*By courtesy of Messrs. J. M. Henderson & Co.*]

[*To face last plate.*

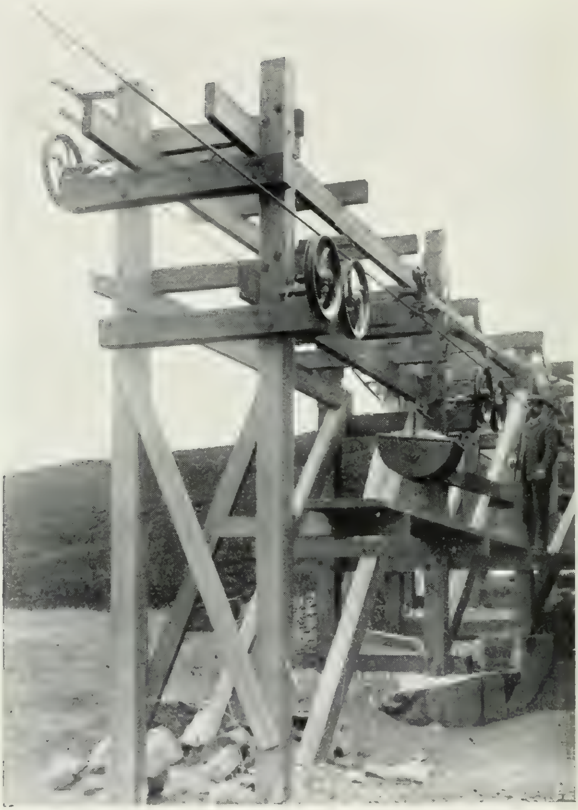

Fig. 62. Aerial Ropeway Terminal.
By courtesy of Messrs. J. M. Henderson & Co.

[*To face p.* 67.

the shunt rail already described picks up the wheels of the carriage, which is automatically released from the rope and which runs round the rail by its own impetus, gradually slowing till it stops. It is then unloaded, pushed round the rail till it drops on the moving cable, on which it is automatically clamped. It then travels empty to the upper terminal, where it is again picked up by the shunt rail and stopped, loaded, and pushed round till it drops on the moving cable, and repeats its journey (Figs. 61 and 62).

For a ropeway of this kind little power is required, as the loads going down help to pull the lighter side up. An engine of 10 or 12 h.p. would be sufficient, and one for running on paraffin would be the most convenient.

The ropeway may be made to convey material both downhill and uphill, and need not even be in a straight line. Angle stations or stagings may be erected to change the line of a ropeway. In these cases, naturally, much greater power will be required. In a mountainous country it may be possible to obtain water power for driving purposes, and do away with the necessity for an engine.

CHAPTER VII

EXTRACTION CONSTRUCTIONS

Slides—Chutes—Flumes—Inclined tramways.

Slides.

If the logs can be taken from the skidway down a slope to a river, railway or road, the next section of transport can be greatly simplified and cheapened, as the logs can be made to slide down. If the ground is suitable, with a fairly deep hard soil, and no rocks, stones or other obstacles are in the way, all that is required is to clear a sufficient width of trail from trees, stumps and undergrowth, and make a furrow by dragging the logs down the line of the trail. For an earth slide of this kind, a gradient about 1 in 4 is necessary, unless the slide can be iced in winter. Should the earth slide run along the side of a hill, it will be necessary to pole the lower side of the furrow to prevent logs wearing away the edge and rolling or jumping out. Logs of about 1 ft. in diameter are laid end to end along the outer side of the furrow and fastened together with a scarf-joint. The scarf of the higher level log is over that of the under one, so that the running log will not catch the point of the join after the poles have worn down. The scarf-joint is fastened with an iron spike or a hardwood trenail driven well in. Stakes are driven into the ground outside the poles to hold these in place.

Chutes.

A timber chute is a slide with both sides built of logs throughout, and in this type the speed of the descending logs can be controlled. The site of the chute is cleared to a width of about 10 ft. Short logs of about 2 ft. in diameter are placed crosswise of the track about every 10 ft., the distance depending on the nature of the ground to be traversed and the weight of the timber to be run. These cross logs are partly embedded in the ground and are notched in the upper side for the two slide logs, which are also notched, to be sunk in it. These latter are about 18 in. in diameter and as long as it is possible to get them and with the least possible taper. They are placed on the cross logs and sunk into the notches about 6 in. apart, with their butts uphill. They are scarf-jointed as before described, and fastened together with iron spikes as well as being

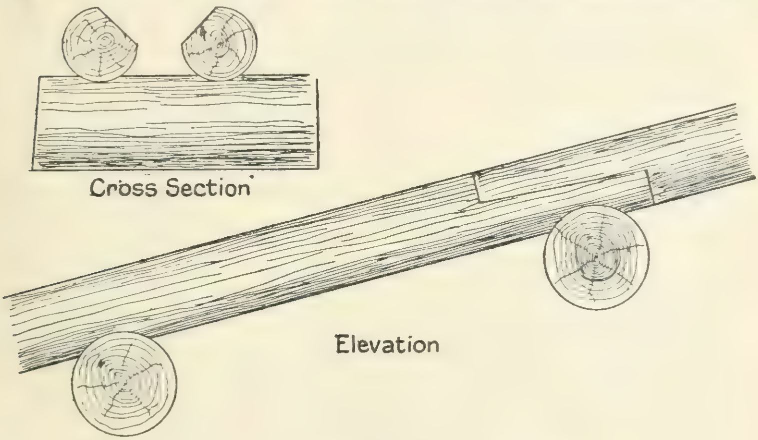

FIG. 63. TIMBER CHUTE. TWO POLE.
SCALE $\frac{1}{4}$ INCH = 1 FOOT.

spiked to the cross timbers. The joints of the two parallel slide logs must not coincide, but must be broken or the slide is weakened.

Where the slide logs are fastened to the cross logs, the former can be notched down a little at the side, and the spike driven through the remaining wood into the crossties. This saves iron and the slide is equally strong. Instead of using iron spikes hardwood trenails may be used, an auger hole being bored right through into which the trenail is driven.

For a timber chute the road has roughly to be graded. Cuts and fills may be necessary if the chute is a long one, and on steep side hills it must be supported on the outer side by crib work. Crib work may also be used instead of filling in crossing a depression.

When the slide logs are fastened in place, the inner faces are chopped smooth and even with the axe into the shape of a wide "V." The edges of the chopped faces are marked with a chalk line, and the chopping carefully and correctly done, or the running logs may jump the chute (Fig. 63).

If all the logs have to be brought to the end of the chute and be dumped there, the last part of the chute should be level so as to check the speed. The last few slide logs at the terminal should be lower on one side than the other and the logs will dump themselves at that side.

Switch.

If there are several dumping places on the chute, the logs may be dumped at each place in turn by means of a pole switch or "kicker." This is a pole 6 in. in diameter and long enough to reach from one crosstie to the next. The slide log on the dump side is cut down a corresponding 6 in. deep and the length of the pole. The kicker is then placed diagonally across the chute on top. A hole is bored right through each end of the kicker and down into the slide log. Into these holes iron pins are dropped which keep the kicker in place. When a descending log strikes the kicker it is thrown out of the chute. When it is desired to close the switch and let logs run past, the pin in the kicker at the side away from the dump is withdrawn, and the kicker is brought round and pinned into the cut in the dump side slide log, which it just fills up. The chute is then open and the logs will run on (Fig. 64).

The crossties should be braced or have stakes driven in against them to prevent side movements. The most suitable grade for a chute is from about 1 in 4 to 1 in 8. If steeper for short distances, there is a greater risk of breakage. A grade less steep can be employed if the slide is greased, and still less if iced.

In very steep sections it will be necessary to check the speed of running logs. This is done by means of two goosenecks inserted into the slide logs. These goosenecks are made of 2 in. round or square iron as shown in Fig. 64. At the place where it is desired to brake the logs, a hole big enough to admit the gooseneck easily is bored right through each slide log from the top. The holes must be exactly opposite each other, as if one gooseneck catches the log before the other, the log will slew round and jump the chute. The object in boring the holes right through is to let any

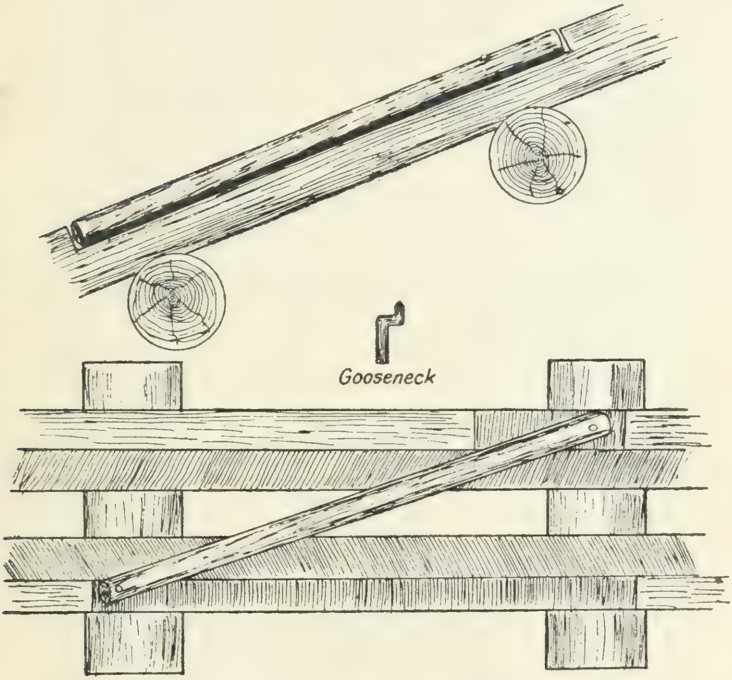

FIG. 64. POLE SWITCH FOR CHUTE. SCALE ¼ in. = 1 FT.
UPPER: SIDE ELEVATION. LOWER: PLAN.

chips, scrapings, and other dirt fall through instead of choking up the hole and necessitating cleaning it out each time it has to be used. When it is desired to brake the logs, a gooseneck is dropped into each hole. When the log passes over them, the sharp points dig into the bark and slow it up.

Braking.

The goosenecks are not permanently fixed, as it may not always be necessary to check the speed at any particular place. For example, heavy logs may need checking while light ones might not; hardwood and barked logs may require braking when softwood and unbarked would not.

No hard and fast rule can be laid down as to the radius of the curves. They must be calculated so that they will allow the running of the longest logs without jumping. At the curves, a second slide log should be placed above the lower one on the outside to prevent jumping out. At the curves also the slide logs may be slightly notched on the outer side to assist in bending them to the shape.

A chute is usually begun at the bottom and gradually built upwards. A gang of men goes ahead and cuts the road, fells the trees, cross-cuts the slide logs and crossties, and prepares them for placing. Another gang with animals hauls the logs into place. A couple of men follow with auger and axe, and spike slide logs to the crossties. Then three men hew the running faces roughly, and lastly comes the principal hewer to finish the faces evenly with his axe.

At the top of the chute, skids are placed on the level at right angles to its line. Logs are dragged to these skids and rolled over them into the chute.

If the logs drop directly from the chute into water, they must not leave it at too steep an angle or the logs may be lost or damaged. The chute in this case must be extended out over the water nearly level, and the grade from the steep chute gradually changed to the level of the extension piece (Figs. 65 and 66). Crooked logs cannot be sent down a chute—the crook must be cross-cut out.

Chuting.

In operating the chute, logs of similar size and character should as far as possible be sent down together—hardwood together; softwood together; barked logs together; heavy logs together, and so on, otherwise some logs may catch up those in front and cause a jam.

When the whole of the timber has been sent down the chute, the chute itself is taken to pieces from the top and the logs of which it is composed slid down and sent to mill or market in the same way as the others.

Fig. 65. Timber Chute: British Columbia.
[*By courtesy of Canadian Government.*]

[*To face p. 72.*

FIG. 66. TIMBER CHUTE SHOWING PROJECTING APRON: BRITISH COLUMBIA.
[By courtesy of Canadian Government.]

[To face p. 73.

The chute may be constructed with round poles only and no " V " shaped face made, but it would require more timber, and it is questionable if it would cost less, while if it is worked over a long distance or a long period, it is not so satisfactory, and it is worth while constructing the chute as described.

However, if this is not feasible for any reason, the other may be made in the following way: The track is graded as before, and cross-timbers are laid down. On the outside are placed lines of logs, 2 ft. in diameter, end to end, and jointed. These are notched and spiked or trenailed as before. The distance between the parallel lines is about

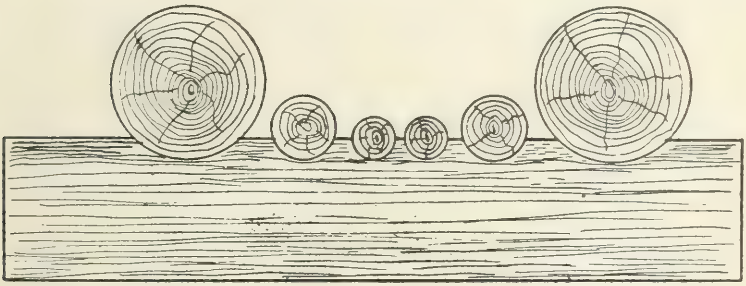

FIG. 67. SIX POLE TIMBER CHUTE. SCALE ⅜ inch = 1 foot.

3 ft. Between these side logs are laid smaller poles about 9 in. to 12 in. in diameter in three or four parallel rows and these are also fastened to the cross-timbers. Fig. 67 will show the construction and the trough formed by the logs and poles laid down as described, and down which the logs are run.

Adaptations of this chute can be made to suit local conditions and requirements, and built lighter if only required for cordwood or smaller product, or heavier for the largest logs (Fig. 68).

Flumes.

Logs and sawn lumber may be brought from high-lying areas for long distances by means of a flume, should there be a sufficient water supply available. A flume is simply a huge wooden gutter to carry water, built on a slope from the forest to the road, river, railway, mill or other destination, and the logs or sawn lumber are floated down. The heavier the timber to be carried, the stronger must be the construction of the flume, and it is often possible to construct and operate this form of transport when the topography of the country makes a logging railway impossible.

The flume has the advantage that after it is constructed, the cost of operating is comparatively small and the volume of timber it can deal with is great. To save expense it is carried on the ground as far as possible, but as it must be carefully graded and aligned, there is sure to be a certain amount of excavation and filling, crib work and trestle work, necessary to preserve a suitable gradient. In laying it out the line must be surveyed as carefully as for a railway.

Where trestle work is built, special care must be taken to get firm footing for the trestles, and particularly the same kind of footing for both legs of the same trestle bent. Unequal settling of the trestle causes sagging or warping of the flume, and consequent spilling over of water at the defective places. This water softens the ground at the critical spot and causes further sagging and leakage and possible ultimate collapse. Leakage is bound to occur to some extent in any case, as the flume is only roughly built, but it should be controlled as far as possible.

A good water supply is essential, but to have this only at the head of the flume is not sufficient. Provision must be made for storage not only at the head but at different places along the flume if it is a long one, from which supplies can be led in by means of subsidiary flumes. If water was only available at the head, it would in time fall so low that the logs would strand or jam.

The flume is usually constructed of two sides joined in the shape of a "V" at an angle of 90°. This in practice has been found to be the best shape and the most economical of water. It not only requires less water than any other shape, especially if made with a backbone, but it gives more clearance to the passing log, while the joint is easier to make

Fig. 68. Large Timber Chute: Canada.
[By courtesy of Canadian Government.]

[To face p. 74

and is more watertight than if the flume had three sides. Further, as less water is carried, the trestle work need not be so heavy.

A constant grade should be maintained as far as possible, but where this cannot be done in particularly difficult

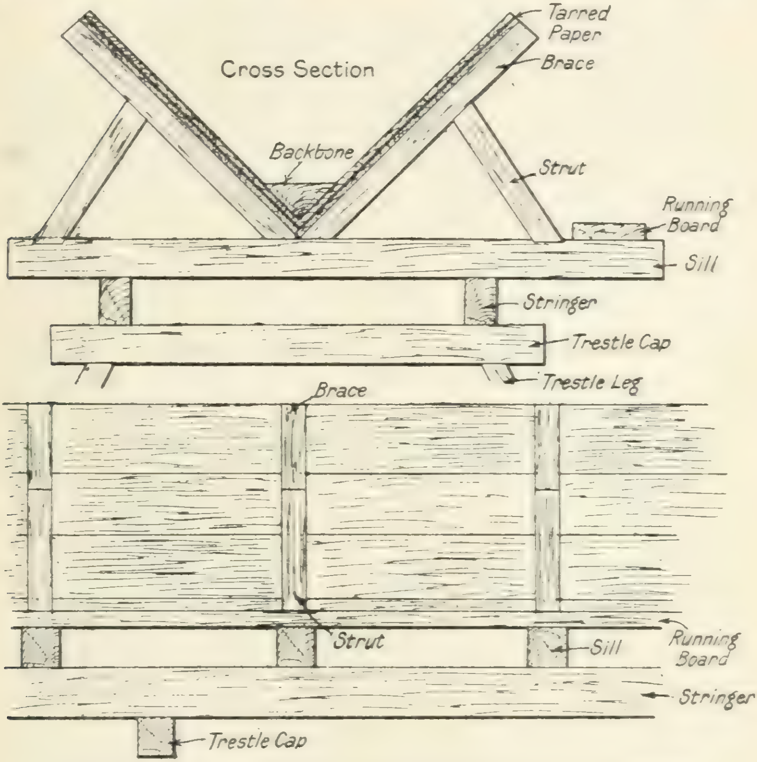

Fig. 69. Log Flume. Side Elevation and Cross Section.
Scale ⅜ inch = 1 foot.

country, the flume may be made in sections at different levels. If no lake is available, a stream would have to be dammed and a pond created between the terminal of the higher section of the flume and the next lower. The logs coming down the higher section would fall into the storage pond and be floated across to the entrance to the next section.

Curves should be avoided as far as possible, but where they are necessary they should be wide to give ample clearance to the longest log. The flume itself should also be widened at a curve and the outer side built higher than the inner one.

Construction.

The sides of the flume are made of 2 in. thick planks. The flume shown in the drawings has a side of 4 ft., but all dimensions and thicknesses can be graduated down or up as the flume is smaller or larger. The planks are usually sawn in lengths of 16 to 24 ft. and 12 to 14 in. wide. The cracks between the planks are covered by strips 4 to 6 in. by 1 in. nailed over them.

In building a flume work begins at the top end, and therefore necessitates a portable or other sawmill at that point, which should be moved down as work progresses, to save time in sending down material. Carpenters make the " V " box in sections and send each section down the gradually extending flume, with its braces and other accompaniments all ready, and the sections are put together by gangs in waiting.

The construction of light trestle work for flumes will be described later, but where it is necessary it is. of course; erected before the " V " box is placed in position.

When trestle work is erected to carry the flume over gullies or depressions of any kind, the caps of the trestles should be of 4 to 6 in. sawn lumber. On the caps are laid the stringers to support the cross pieces which carry the " V " box. These stringers are about 5 in. square, more or less according to the size of the box and the distance between the trestles, and are placed 5 ft. apart from centre to centre.

On the stringers at intervals of 4 ft. are carried the cross-timbers or sills, 9 ft. long, of sawn lumber 6 in. deep and 4 in. wide. The " V " box is not placed in the middle of these sills, but 1 ft. to one side of it, so as to allow a running board to be nailed on the sills at the other side for the use of men running the logs, repairing the flume, and so on.

The "V" box is set in its position on the sills and is supported at each sill by side pieces the length of the sides, and by struts, both side pieces and struts being of 4 in. square sawn lumber.

All nails are driven in from outside into the "V" box and are clinched down stream, so that when the sides of the box wear thin and logs hit the nails, they do not catch and pull out the points of the latter and so loosen the joint, but drive them farther in and tighten it. The process of building is continued till the terminal is reached.

If a backbone is nailed into the bottom of the box, it is of 6 in. square lumber sawn diagonally to fit the vertex. It both strengthens the box and makes less water necessary for floating.

Instead of the sides of the box being made from single 2 in. plank, they may be made from two thicknesses of 1 in. plank with a sheet of tarred roofing paper between. This costs more, but the box is tighter and there is very little leakage, while repairs cost less (Fig. 69).

The bracing is closer at the beginning and end of the flume and at curves, where there is a greater strain. Sharp curves should be avoided immediately below a steep gradient. The most satisfactory grade for a flume has been found to be 3 in 100, but it may be as much as 8 in 100. Anything steeper than this should only be for very short distances.

As already stated, a lake or artificially created storage pond is necessary at the head of the flume. If no lake exists, the stream from which it is intended to draw the water must be dammed to hold up sufficient quantity. A dam can be built on the same principle as that described in Chapter X, but need not, of course, be of such heavy construction. The head of the flume can be continued into a sluice gate in the dam and the sluice only opened when fluming is going on, or when for any other reason it is desired to send water down. In a hot country water should be run into the flume during the dry season even if fluming is not proceeding , as this keeps the joints tight.

Logs are brought from the forest or skidway and dumped into the pond where they can be stored in readiness. When it is intended to send them down, the sluice gate is opened and the logs in the pond floated across and into the flume. Water must be admitted into the latter some minutes before the first log is put in, and the sluice gate left open for a few minutes after the last log of the drive has gone. Heavy logs are sent down separately from light logs, as they travel quicker than the lighter and would catch them up and cause a jam. They are put into the flume at the rate of about nine a minute. The average speed of a flume is about three miles per hour.

Most water is required at the bottom end of a flume, as the gradient there is less, while the amount of water required on a high grade flume is less than in a low grade one, as in the former case the flume is more or less a wet slide and the logs run easily.

Should it be intended to put logs into the flume at different places along the route, rollways or skids must be constructed at the level of the top of the box to roll them in, and at such a point the box must naturally be very greatly strengthened. Branch flumes can be laid from valleys along the route into the main flume, and where they join the latter care must be taken that they do not join in a sharp curve or angle, but that plenty of room is given for the longest log to turn the corner easily.

Men patrol the different sections of the flume carrying pike poles—short poles with a spike in one end—to keep the logs moving. The average labour required is about two men to the mile of flume. If the grade is high and there are few curves, fewer men will be required than if the reverse is the case. A telephone should be installed all along the line of the flume to let the patrols know when a drive is beginning or ending. A flume with a 48 in. side will take a log 4 ft. in diameter ; the length of the log it will take will depend on the sharpness of its sharpest curve.

Terminal.

There are various kinds of flume terminals, and the one chosen must be adapted to the kind of handling the logs are to have after they leave the flume. Possibly they may spill right into a river or lake for further driving or floating, in which case no construction is necessary. If they are to

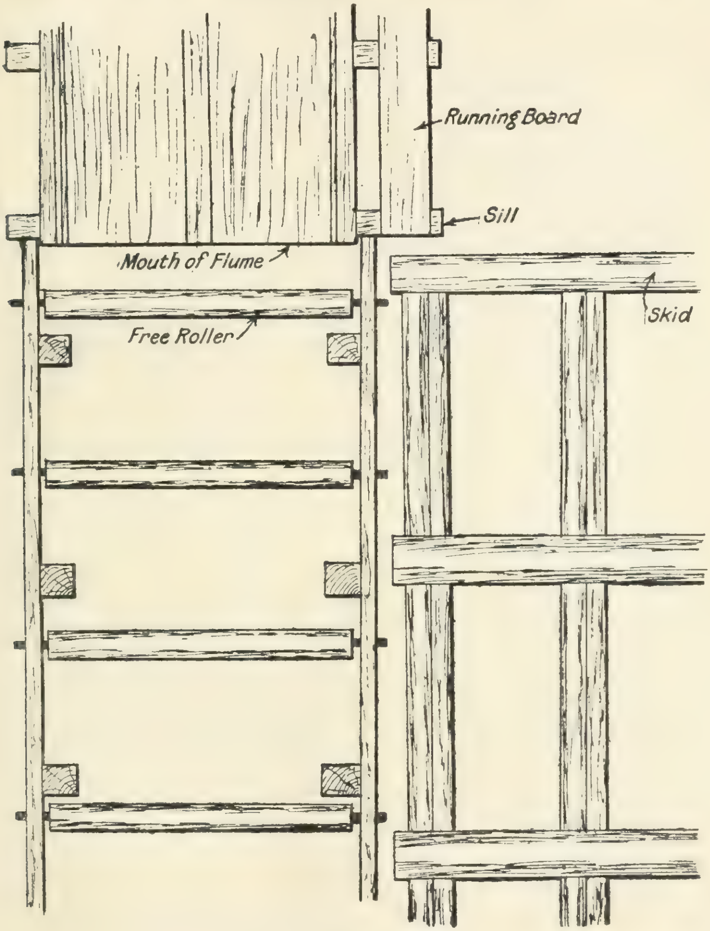

FIG. 70. FLUME TERMINAL.
SCALE, ⅜ inch = 1 foot.

to be handled on land, however, a framework can be erected at the mouth of the flume to carry rollers along which the logs are hauled as they leave the water. Skids or rollways at right angles to the line of the flume lead from the rollers to the ground, railway platform, etc., and the logs are rolled or slid down as they come in and disposed of as may be necessary. Fig. 70 shows a simple terminal, but modifications to suit local conditions will naturally occur to the operator.

The water in the flume, being no longer required, is led by a channel into the natural drainage system.

Inclined Tramway.

An inclined tramway may be built to carry logs or sawn lumber from high to low ground if the topography is suitable. The gradient may run as high as 45 per cent., or even more for short distances. It should be constant as far as possible, although slight changes are allowable.

The roadbed is roughly graded, and any necessary crib or trestlework built, and sleepers and rails are laid down as described in Chapter IX. The cars are lowered and hauled to the top by wire rope worked by a winding engine of suitable power for the loads.

If a double track is laid down, two cars may be in constant use without any power being employed, the loaded car going down hauling the empty one up. In this case the two cars would be connected by a wire rope of such a length that when one car is at the top the other is at the bottom. The wire rope is passed several times round a drum at the top, furnished with a powerful brake, by which the speed of the descent can be regulated. Horizontal rollers running on pins are laid at intervals on the track between the rails for the wire rope to run on. Otherwise the moving rope will cut the sleepers and be damaged itself.

CHAPTER VIII

ROADS, TRAMWAYS, TRESTLES

Pole roads—Corduroy roads—Tramways—Cribwork—Pile and frame trestles.

Pole Road.

In a long haul from forest or skidway, in a definite line, instead of skidding logs on the ground a pole road may be laid down, along which a series of attached logs can be hauled by animal or mechanical traction. This is on the same principle as the timber chute, but laid on level or fairly level ground.

A track through the forest is first cleared of stumps and brush, wide enough to lay down the pole road on one side of it, and give ample clearance for either the animals or tractor which will draw the logs. The track need not be graded, as it is intended to follow the ground level as far as possible, and any deep holes or streams may be crossed on cribwork. The pole road itself may be of from 2 to 5 poles, as described in Chapter VII for the construction of a chute. Short supporting cross-timbers are laid every 12 ft. and embedded in the ground, so that the surface of the latter may as far as possible support the slide logs. These are scarf-jointed and spiked end to end and notched and spiked where they rest on the sleepers. Hardwood trenails may be used instead of spikes.

In hauling logs on a pole road, the first log is rolled into the slide and the hauling chain from the team or tractor is attached to the after end of the log by an "L" hook, as shown in Fig. 30. It is then hauled forward far enough to give room for the next log to be rolled in. The two logs are attached end to end by coupler grabs, as shown in the illustration in Fig. 34, the "L" hook attached to the after end of the second log, and the process repeated till the load is made up. The hauling chain is then attached to the forward end of the first log by a grab hook and the load is hauled to its destination. As many as 20 or 30 logs may be hauled in one turn.

If part of the pole road should take the form of a chute, or should there be any steep place where the logs may run of themselves, they are not coupled to each other and the hauling chain is attached by the "L" hook to the after end of the last log, which pushes the others in front of it. When the last log runs, the hook detaches itself and the load is picked up again at the next level stretch.

Corduroy Road.

In swampy places a road for sled or other traffic may be corduroyed. A track as wide as may be required is cleared and a thick layer of brush is laid on it. On the brush foundation, crosswise of the track, poles are laid close together, side by side. The diameter of the poles is not important, but they should be strong enough to carry more weight than it is intended to send over the road. The cross poles should be as long as the track will allow, as the longer they are the greater surface they cover and the better will they hold up the road. The brush foundation can be dispensed with, but is a distinct advantage.

Forest Tramway.

Forest tramways are an economical means of transporting both logs and sawn lumber. The track may be either of round poles, sawn wooden rails or steel rails, and the rolling stock will have wheels to correspond.

A track is first cleared of brush and stumps and the bed graded. If round poles are used for rails, the grade should not be more at any point than $1\frac{1}{2}$ to 3 in 100, depending on the number of animals hauling. The poles should be long straight trees about 1 ft. in diameter and with as little taper as possible, and in laying them the butts should all point one way. They are scarf-jointed and spiked or trenailed end to end and hewed flat on the inner side where the wheel flanges touch.

On good hard ground no sleepers are used, but the poles are laid on the surface about 6 ft. apart and kept in place by stakes driven into the ground against the outer side at short intervals. They need not be staked on the inner side, as the pressure during transportation is all outwards. Ballast is filled in between to make good footing for the animals hauling. At curves, braces are fastened from rail to rail inside, low enough to clear the flange of the wheel, and the outer sides are strongly braced as well.

Where the ground is not of a nature to hold the rails firmly, sleepers must be laid underneath. These are poles laid crosswise every 8 ft., to which the rails are fastened by spikes or hardwood trenails. Poles and sleepers are notched or flattened at the point of contact. The space between the sleepers must be filled with ballast so as to give a level footing for the animals hauling.

The cars for transporting timber on a pole tramway can be made locally. The two pairs of wheels for each car are about $3\frac{1}{2}$ ft. in diameter with a concave face to fit the poles and with a flange of 4 in. on the inner side and less on the outer. The wheels must have sufficient side play on the axle to allow them to adjust themselves to any little widening or narrowing of the track caused by inequalities on the poles. Two heavy sawn timbers about 12 ft. long are bolted to the upper sides of the axles of the front and back pairs of wheels. Across these, and on top at the front and after ends and clear of the wheels, are bolted two bunks of timber about 10 ft. long and 10 in. square, and on these the logs are laid. The hauling gear is attached to a strong pole bolted on the upper side of the middle of each axle and projecting beyond the car at both ends, so that the car does not need to be turned, but can be hauled from either end.

If a sawmill is available in the forest where a rail track is to be laid, the rails should be of sawn lumber, as they will carry much more traffic with less power.

The motive power may be either animal or mechanical. Light locomotives have been used with success on such roads, but where this is done, practically the only saving in building a wood railroad instead of one with steel rails is the first cost of the rails. The road has to be as carefully graded, built and maintained, and the rails wear more rapidly, especially in wet country, while the rolling stock tends to jump the track to an annoying extent.

The rail should be of 6 in. by 6 in. hardwood, but may be made up of two pieces nailed together, the upper of better and the lower of poorer quality. The sleepers are either of the ordinary size or may be round timber of equivalent strength and 7 ft. long, spaced about 24 in. apart centre to centre. The standard gauge should not be adhered to on a railway of this kind, but should be a narrow gauge. The life of the rails may be lengthened by having hoop iron screwed to their inner faces, and hoop iron in any case must be screwed to the inner faces of both rails at all curves. The rails should not be in lengths of more than 12 ft., so that in the event of one becoming defective at any place, only a short length has to be replaced.

The road bed for this railway must be levelled and graded as for a standard railway, and must be ditched at both sides with cross ditches between.

Tramways of narrow gauge form an easy and economical method of transporting logs or sleepers and other sawn lumber on level ground or where there is no steep gradient required to bring the produce from a higher to a lower level. The hauling power may be either man or animal, or light locomotive suited to the gauge and load to be hauled. If rails of steel are not available, they may be made of any suitable wood the forest affords locally. The most useful gauge for a tramway is 24 in.

If wooden rails are used, they should be 5 in. deep and 4 in. wide, and if faced on the inner sides with hoop iron screwed to them, their life will be very greatly extended. In any case hoop iron must be fastened to the insides of both rails at all curves to prevent the wheel flanges wearing away the rails.

Wood rails should not be long, 10 ft. or 12 ft. at most, as when only a small part of a rail becomes defective, it is a waste of material to replace a whole long rail. At curves the rails may be steamed to shape or the curve formed by very short lengths of rail (Fig. 71).

FIG. 71. FOREST TRAMLINE WITH WOOD RAILS: AUSTRALIA.
[By courtesy of Government of Victoria.]

FIG. 72. FOREST RAILWAY AND TURNTABLE: POLAND.
[By courtesy of Century Timber Corporation.]

[To face p. 84.

Exact dimensions need not be adhered to, but the sleeper should project about $1\frac{1}{2}$ ft. beyond the rails and have a face of 5 in. or 6 in., and be 4 in. thick. Four sleepers should be used for each rail, equally spaced, while if short pieces are used for curves, they must be supported by a sleeper at each end. The sleepers should be sunk in the ground, so that the rails will rest on the surface as well as on the sleepers.

Logs can be carried on a tramway by means of a log carriage consisting of a pair of two-wheeled trucks similar to that described on page 111, but reduced in size to the requirements of the tramway, and will then negotiate curves with ease.

For the carriage of sleepers and other sawn lumber, low, flat cars can be built locally, only the wheels, axles and axle boxes being imported. The wheels should have a flange of 3 in.

Portable Tramway.

Portable tramways are made by various firms, all on much the same principle. The sleepers and rails are of steel, and they have the advantage that they can be lifted and laid in another place expeditiously and with no damage to the sleepers, as is the case when the latter are of wood. In some makes each pair of rails will have the sleepers permanently attached, while in others the rails are wedged into slots in the sleepers after these are laid. The rails are fastened end to end by means of fishplates (Fig. 145).

Switches, turnouts, frogs and so on, ready fitted, are supplied with the rails by the makers.

Turntable.

A handy form of turntable is shown in the illustration of a tramway (Fig. 72). It is a disk of strong sheet iron, sufficiently large to accommodate the rolling stock in use, and is set on a pivot in the middle of the track. Two rails are riveted on its upper side at the proper gauge. The turntable is set so that its rails meet the rails on which a truck is approaching. The truck is propelled on to the turntable, which is then turned to meet any other set of rails going in the required direction, and the truck is pushed on to these rails.

At curves on narrow gauge tramways, the rails should be slightly wider apart and the outer rail raised, as on a railway.

For a permanent tramway, the road bed must be graded, ditched, and constructed generally in the same way as that for a forest railway. Lighter work can be used in the construction of any trestles or bridges to carry the track over gorges or streams. Rails for forest tramways, if of steel, should not be less than 20 lb. to the yard. The work and the usage in timber operations are heavy, and lighter rails do not stand up well.

Cribwork.

Cribwork may be applied to many different forms of construction. The crib is simply a framework of logs of whatever shape and size the particular work may call for. Lines of logs are first placed on the ground and other logs laid on these at right angles and spiked where they cross to fasten them together. Then the same process is repeated in tiers or layers till the necessary height, size and shape have been reached. The diameter of the logs will depend on the actual strength necessary, for example, in the case of a bridge, the weight it has to carry, and so on. If the logs are not long enough for the purpose and have to be joined end to end, they are scarf-jointed in the same way as the slide logs of a chute.

Wherever one log is spiked crosswise to another, the logs should be notched or at least flattened, so as to increase the bearing surface of each log and prevent shaking or rolling, which would weaken the structure.

The cribwork may simply be required to carry a road or rail track over a depression, and in that case when the framework is erected and decked over with poles, the job is done. If, however, it is to stand in water, either still or flowing, the crib must be filled with rocks to prevent its being floated or washed away. For this purpose a deck of poles is laid on the crib resting on the tops of the horizontal logs near or at the bottom, and the crib is filled up with heavy stones of a size which will not slip through between the logs. If the crib to stand in water is a high one, more than one deck of poles should be laid or the lifting power of the water may in time lift the upper part of the crib from the lower, even if the whole crib is well spiked. A deck should be placed every 6 ft. or so in height, and each deck piled up with rock. The crib should not be filled with rock only in its upper portion, as it would be top heavy and any strong current might upset it. If the crib is constructed ashore and has to be floated off, the poles of the deck must be nailed to the logs before it is put in water or they will float away. The rock must not be filled in until the crib is in its place, or it cannot be floated out to it.

Cribwork construction lasts longer if the logs are barked before use.

Trestles.

Trestles are built to carry chutes, flumes, roads, railways and so on, across gorges or deep depressions and over rivers, and are of two kinds, Pile Trestles and Frame Trestles.

Pile Trestles.

Pile Trestles are used in swampy ground where there is no solid bottom on which to set up a frame trestle, and also in stream beds too wide for a bridge span. They are seldom required to carry a light construction such as a flume, but are likely to be necessary in building a forest railway. Pile Trestles to carry a railway of standard gauge will be taken as an example. To carry a narrow gauge railway for locomotives, much the same trestles would be constructed, but in the case of a light tramway, the whole work would be of a lighter nature.

The Pile Bent, that is, each cross row of piles, may consist of from three to six piles driven to solid holding ground or to bed rock, and then cut off at a predetermined height and capped with a heavy timber. The cap is usually of 12 in. square timber placed on the top of the row of piles and spiked to each by spikes or drift bolts of 1 in. iron 2 ft. long. In driving the spikes an auger hole of less diameter than the spike is bored through the cap and down into the pile and the spike driven home. Or the top of the pile may be cut to a tenon and fitted into a mortise cut in the cap. Or a

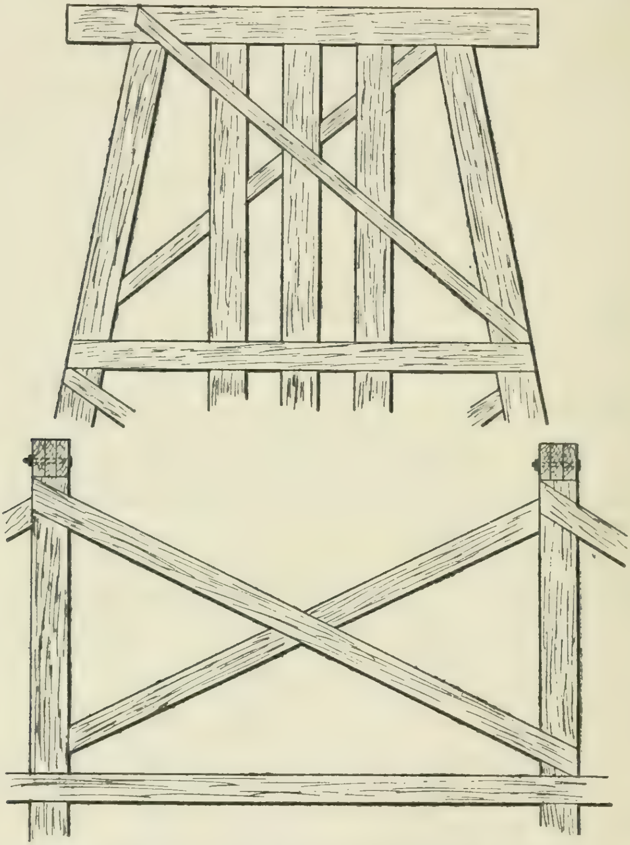

FIG. 73. TOP OF FIVE-PILE TRESTLE:
SIDE ELEVATION AND CROSS SECTION. SCALE $\frac{3}{16}$ inch = 1 foot.

shoulder can be cut in opposite sides of the top of the pile, and instead of the cap being of one timber 12 in. square, two 4 in. by 12 in. timbers may be used resting on the shoulders and bolted together through the pile (Fig. 73).

The piles may be either of round or square timber sharpened to a point. In heavy work they are sometimes shod with steel, but this should not be necessary in the construction of a forest railway. A simple method of shoeing, however, is to nail on two strips of iron at right angles to each other and crossing on the point of the pile. The ends are nailed up the sharpened sides. The top of the pile must be ringed to prevent its fraying under the blows of the pile driver. The pile should be slightly shaved away at the top, and a ring made of $\frac{1}{2}$ or $\frac{3}{4}$ in. iron shrunk on to it. The ring receives the blows, and after the pile is driven and cut off to its proper height, the ring is taken off and used again. In constructing a low trestle with three piles, each pile is driven vertically, one in the centre and one on each side 2 ft. from it. When four piles are used, the two inner ones are 3 ft. apart, centre to centre, and the outer ones each 26 in. from the nearest middle one, centre to centre. If five or six piles are used, the two outer ones are given a batter, which may be of 1 to 12, to 1 to 4. The top of each outside batter pile should be 1 ft. from the pile next it after it is in place.

The whole of the Pile Bents on the section are driven before the cutting-off points are fixed, so as to bring them to the correct grade. When this is determined, they are marked with nails driven in, and after the tops are cut off, the caps are fixed in place.

Low trestles are seldom braced, but if over 8 ft. or 9 ft. high, they must be braced diagonally on both sides, with 3 in. by 6 in. sawn timbers or poles of corresponding strength to prevent lateral sway. The top end of the brace is spiked to the cap and the lower end to the opposite pile just above ground, and to any intermediate piles where it crosses. Longitudinal bracing may also be required. If the Bent is a high one, it is divided into sections every 15 ft. or so by horizontal braces and each section is braced diagonally as described. (See Fig. 73).

The distance between Bents should be about 14 ft.

Frame Trestles.

Frame trestles are built when the bottom is a good one, and will hold up the weight without sinking, or they may rest on piles driven into soft ground. They may be built either of square sawn timbers or of round timbers of equivalent strength. The former is easier to fit and make stiff owing to its larger bearing surface, and is more lasting.

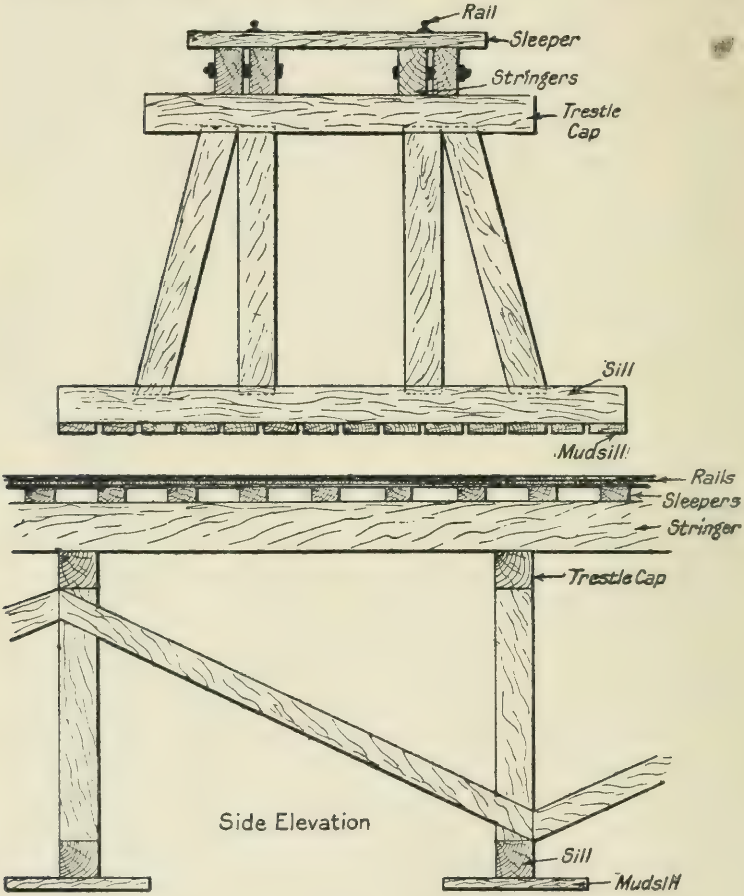

FIG. 74. FRAME TRESTLE. SCALE $\frac{3}{16}$ inch = 1 foot.

The ground is levelled crossways of the road where each Bent is to go. On this levelled ground are placed mudsills, planks of 4 ft. by 12 in. by 3 in., close together at right angles to the line of the Bent. On the mudsills is laid the sill of the Bent, 12 in. square timber and 14 ft. long, or long enough to project about 2 ft. beyond each of the outer legs. The legs of the trestle are also of 12 in. by 12 in. Two are now erected perpendicular on the sill, each about 18 in. from its centre. The length of the legs is that necessitated by the height of the trestle. They should be tenoned at each end to fit into mortises in the sill and cap, to both of which they are securely spiked, although tenoning is not absolutely necessary. The cap should also be of 12 in. square timber and 9 ft. long. Then another leg of the same sized timber is spiked outside each perpendicular leg, one end resting on the sill about 2 ft. from the end and the other against the top of the perpendicular leg. The sloping leg is sawn to shape, so as to fit close against the sill, the perpendicular leg, and the cap, to all of which it is spiked. The batter of the outside leg should be about 1 to 4.

The Bents should be set up about 12 ft. apart, centre to centre, as before ; the cut-off points must be decided before the caps are spiked on, so as to conform to the grade. Diagonal bracing will be required longitudinally to prevent swaying, unless the trestle is a very low one (Fig. 74).

Flume Trestle.

A frame trestle to carry a flume is of much lighter construction and is also better and more easily made of sawn lumber, although it can be built of poles of equivalent strength. As, however, the construction of a flume necessitates a sawmill, the lumber for the trestle should be easily obtainable. The size of the caps of the trestle and of the stringers and other timbers will depend on the size of the "V" box of the flume, the amount of water carried, and the distance between the bents of the trestle. Similarly with the bracing, which will be nearer or farther apart as the weight to be carried is greater or less.

The flume taken as an example in Chapter VII has a 4 ft. side, and we will assume a frame trestle to support it. Each completed upright is a Bent and, if not too high, can be put together flat on the ground and raised up on end either complete or nearly so. It may also be built up

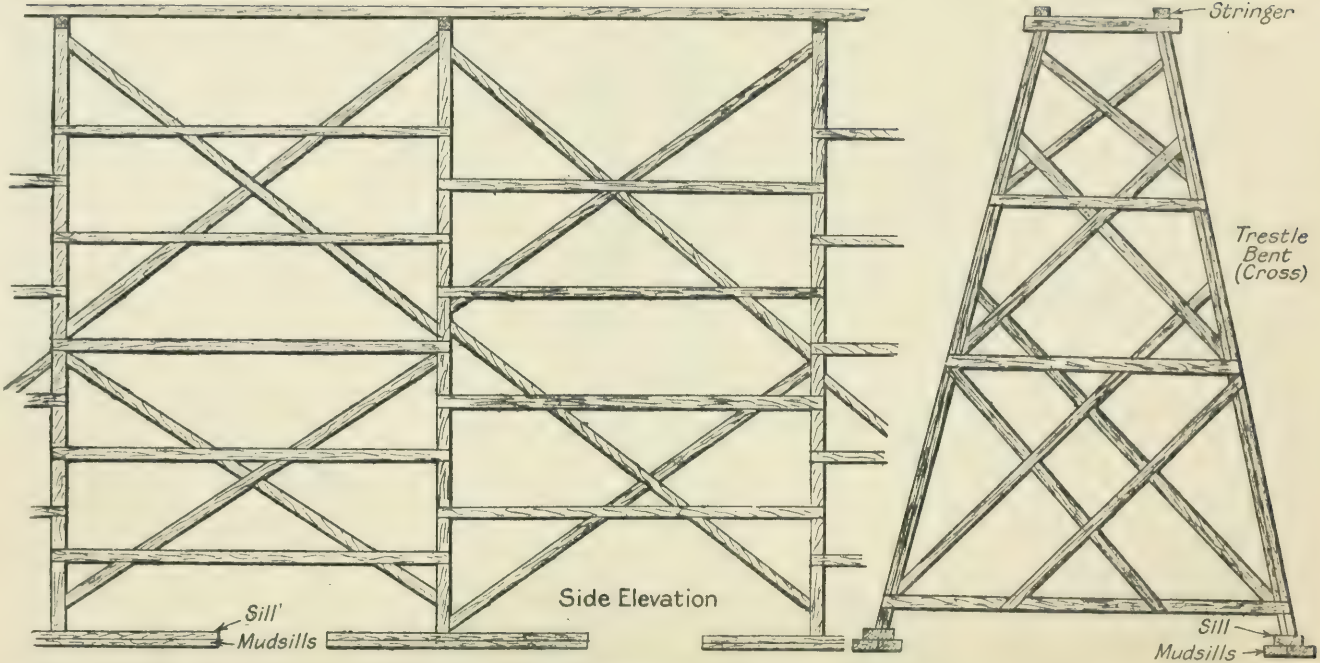

FIG. 75. FLUME TRESTLE. SCALE $\frac{1}{8}$ inch = 1 foot.

standing, being temporarily stayed till the next Bent is ready to connect with it.

Suppose the trestle to be 25 ft. high, each Bent will have two legs. Each leg is made of two thicknesses of planking, 6 in. by 2 in., nailed together. The planks of which the leg is made should not be of the same length, but of different lengths, so as to break joint and give an overlap of 6 ft. or 8 ft. If longer than 25 ft., the leg is made up in the same way of as long lengths of planking as possible, but with the long overlap so as to strengthen it. All nails must be clinched.

Mudsills are laid on the spot where each leg will rest when erected. These are long planks, 12 in. by 4 in. Two are laid side by side close together in the line of the flume for each leg to rest on. On the top of these mudsills is placed the sill proper, one plank of the same size, covering half the inner surfaces of the mudsills, to which it is firmly nailed, as shown in Fig. 75.

In deciding the distance from each other of the two sets of sills, it is necessary first to settle the distance apart the tops should be when erected with the legs having a batter of 1 to 4. This will give the shape of the Bent and consequently the distance apart of the feet. The sills do not require to be on the same level, but if they are not, one leg of the Bent must be longer than the other, so that when erected the Bent will stand absolutely plumb.

The horizontal braces are now nailed on and the length of the two lowest must be carefully calculated, as once nailed on they govern the batter of the legs. The horizontal bracing is of 6 in. by 2 in. The lowest brace is nailed on first, 1 ft. from the bottom end of the shorter leg, if the legs are unequal, and as far from the bottom end of the longer leg as will make the Bent plumb when erected. It is nailed into all four planks of the two legs. Ten feet up the second brace is similarly nailed. Ten feet above that again a similar brace. This leaves about 5 ft. of the legs above the last nailed-on brace. The top brace is not nailed on till the cut-off points of the legs have been fixed.

The diagonal bracing of 6 in. by 1 in. is now nailed on.

This bracing is begun at the bottom also, and the method is clearly shown in Fig. 75. All bracing is nailed to the legs with two nails at each end, and also at all points of contact. The Bents are stood up about 15 ft. apart with the feet nailed to the mudsills and are connected with each other by horizontal braces spaced 4 ft. or 5 ft. apart. Diagonal bracing from one Bent to the other is nailed on 7 ft. or 8 ft. apart, except at points where there is additional strain, such as the loading places along a flume, when it may be as close as 2 ft., depending on the height of the trestle, the length of span and the pressure it has to withstand. All the longitudinal bracing is of 4 in. by 2 in.

When the cut-off points have been ascertained and the top brace is nailed on, the caps are spiked to the top of the trestle, and the latter is complete.

A trestle may be built on these lines up to 50 ft. or 60 ft. in height, but for that height five legs are used. First it is necessary to settle the width the trestle is to be at the top. The outside legs have a batter of 1 to 4. The centre leg is exactly half-way between the two batter legs, and the other two exactly half-way between the middle one and the two outer ones. Mudsills and sill, as before, are laid down for each of the five legs, and the lower part of each leg is set up on the sill, to which it is nailed. The legs are made up of thicknesses of 6 in. by 2 in. planking with long overlap as before. A high trestle Bent is built up in sections, and is temporarily stayed as it grows, until it can be connected with others. Horizontal braces of 4 in. by 2 in. are now nailed across each of the five legs, beginning with the lowest brace a little above the ground. Ten feet up another brace is nailed, and a third 10 ft. above that. Then at distances of 6 ft. until nearly the top is reached. The top brace is, as before, nailed after the cut-off points have been marked.

Diagonal bracing of 4 in. by 1 in. is now nailed on, beginning at the bottom on the opposite side of the legs from the horizontal bracing. The diagonal braces should be 5 ft. or 6 ft. apart. When the top is reached, corresponding diagonal cross braces are nailed all the way to the bottom.

All braces are nailed with two nails at each end, and two nails at every point of contact with other braces.

The cut-off points should not be marked till several hundred feet of trestle have been erected. After they are cut off the caps are spiked on, then the stringers, and after that the sills and running board, and the trestle is ready for the flume.

CHAPTER IX

FOREST RAILWAYS

Logging railways—Reconnaissance—Locating—Drilling and blasting—Handling dynamite—Culverts—Laying sleepers and rails—Locomotives—Fuels—Log cars.

If a very large quantity of timber is to be logged, and if topographical and other conditions are suitable, transporting logs by forest railway is perhaps the most satisfactory and probably the cheapest method. No definite figures can be given as to the volume of timber which would make a railway desirable from an economic point of view. Much will depend on the quantity of timber to be logged, the total cost when placed on the market, the market price, and other factors. It will be necessary to calculate these, and estimate the cost of the railway, both in construction and operation.

A railway has many advantages. It will carry any kind of timber and is not, like a river, only possible for timber that will float. It can carry timber all the year round and does not depend on seasonal conditions. With a forest railway in operation the logger can slow up or shut down temporarily when his market is overstocked, and only cut down and haul logs as they are wanted at the mill. He saves heavy overhead charges among other things, while he need not have a lot of cut logs lying in the forest exposed to fire risk and damage from other causes.

If logs are floated or driven, even under the best conditions there is sure to be some loss in transit, and many of the logs are broken and damaged by rocks, while logs inevitably arrive at the mill carrying a considerable quantity of sand and gravel. Apart from anything else, logs arriving at the mill clean mean a considerable saving in saws and their upkeep. All this must be taken into consideration when deciding the main method of transportation from any area to be logged.

Forest railways for logging purposes only are usually temporary constructions, and may be quite roughly built. Bridges, culverts, and so on can be constructed from the material lying to hand in the forest, and do not require to be of steel or concrete.

The line may be either the standard gauge of the country, or it may be narrow gauge or anything down to a couple of feet. Narrow gauge is naturally the cheaper to construct; the road bed costs less, the rails are lighter and cheaper, as are the locomotives and other rolling stock. It is also easier and cheaper to move the track if this has to be done often, and on soft ground it is cheaper to maintain, owing to the traffic being lighter. These sum up practically all the advantages of a narrow gauge road. Bridges, culverts, and so on, cost about the same for narrow gauge as for standard gauge.

If a very large amount of timber is to be hauled over a long period, the increased initial cost of the standard gauge road will not add much to the cost per 1,000 ft. of timber, and if possible a standard gauge should be installed. More powerful locomotives and larger cars will be used and will cost more, but they will haul heavier loads of timber and the running cost per 1,000 ft. will be reduced. But a greater advantage is that cars can be run from their first loading point right to the ultimate destination of their contents without unloading and reloading. Repeated handling is a source of heavy direct and indirect expense. The choice of gauge, therefore, must depend on local conditions, and requires careful consideration, while the most careful consideration also must be given to the location of the main line. Low grades and easy curves mean higher construction costs, but lower operating and maintenance costs, and vice versa.

Reconnaissance.

In a flat country, with no natural obstacles and good bottom, locating the track is an easy matter, and it can be as nearly a straight line as possible. The object of a forest railway is in all circumstances merely to bring the road to the timber by the shortest and cheapest way.

In a hilly or mountainous country, it must be kept in mind that ultimately the timber will come to the lowest level, and reconnaissance for either railway or road should begin at the place the lowest level enters the area. This will probably be the outlet for the natural drainage of the area, possibly a valley with a river or stream at the bottom. The main line will probably follow more or less this natural drainage, and data should be obtained showing the highest level to which floods have reached, and the road bed must be built above this to avoid being washed away. If no data exist, a fairly safe estimate can be formed by observing marks on the vegetation, grass, dirt, wood, etc., which have drifted up and remained.

Within reason, the shorter the road the better, but here again only local conditions will enable one to judge. If heavy cuts and fills, bridges, trestles, and culverts can be avoided, it is better to lengthen the line. Grades should be in all cases as easy as possible. Steep grades mean a heavy strain on the locomotives and higher maintenance charges. Sharp curves should be avoided, especially on a descending grade, as the rolling stock is apt to jump the track. These remarks apply to the main logging line.

The subsidiary or spur lines in a flat country can be located practically anywhere, but in hilly country they will, like the main line, probably follow the natural drainage. They are only to be used for a limited time and for a limited amount of traffic, and can be located with less care and built more roughly and cheaply. As the speed will at all times be less than on the main line, there may be sharper curves and steeper grades. When the railroads can all be located along the lines of natural drainage, it is particularly an advantage where animal hauling or skidding is in operation, as all this will be downhill, while slides and chutes may be used to bring the logs to the railway. If power skidding is used, however, a wider choice is given to locating the main line. It may be along the crest of a hill, should that be more convenient and cheaper to construct, as a power skidder can haul logs as readily uphill as down. In fact it is probably more satisfactory to haul uphill, as in power skidding downhill, logs may start to run and tangle up the cable, that is, if it is ground skidding. With the overhead power skidding, it does not matter whether it is up or down.

Spur lines should be roughly parallel and leave the main line every 1,500 ft., if the stand of timber is a close one. This should not necessitate animal haul of more than a quarter of a mile. On the main line, grades should be about 3 per cent. and curves 12°, while on the subsidiary lines grades may be 6 per cent. and curves 15°.

Locating.

When the approximate line of the railway is decided, a trial line of tangents is located, sighting along straight sticks which are placed at intervals of 100 ft., and cutting down trees and clearing away bush for the purpose. In the absence of more scientific methods, the appropriate grades and the curves for connecting the tangents may be obtained simply by trial and error.

Approximately accurate estimates of the cost can be made after the location is definitely fixed. For the purpose of estimating the quantity of earth and rock to be removed, cross sections are taken along the track every 100 ft. and where the configuration changes.

In countries not subject to heavy rains, it is an advantage to construct the road bed the year before it will be used, as this gives it time to settle before there is any traffic, and operating will proceed more smoothly. Where the road is liable to washouts from heavy rains, however, this cannot be done.

Construction.

Construction commences by cutting a line 100 ft. wide along the site of the proposed main track, clearing away the standing timber and brush. For spur lines the clearing should be wider, to allow for building skidways at any part of the track. Stumps should be removed if possible, either by blasting or by using the monkey winch described in Chapter IV. If they are removed by blasting, this loosens the earth for a considerable distance all round and may cause a soft spot in rainy weather, which may be difficult to fill and which may cause the line to subside. The stump may be left where it is, if it is quite clear of any part of the actual track and cut down level with the ground. It may also be left if it is in the site of a proposed fill and can be covered with not less than a foot of earth. Small-sized trees should be removed bodily, roots and all, by means of the monkey winch.

Stumping; Construction.

If dynamite is used in blasting stumps, more of the explosive is required in blasting in light dry soils than in heavy, damp ones, as much of the force of the explosion is lost. In blasting a stump with a long taproot, the charge is placed at a depth of 1 ft. under ground for each foot of stump diameter. Trees with lateral roots are more difficult to blast than trees with taproots and require a bigger charge and a higher explosive, one cartridge being placed under each lateral root and half a dozen near the centre of the stump. They are fired simultaneously by an electric charge firer. A heavy chain should be bound tightly round the top of the stump or, when the charge goes off, the stump is apt to split instead of being blown out. The holes for charging with dynamite are bored with an auger very slightly larger than the dynamite cartridge. If the auger is not long enough, it can be welded to an iron rod of suitable length. Holes in stumps are charged in the same manner as those in rock, which is described later.

The construction to be described is that of a road of standard gauge, that is, 4 ft. 8½ in. from rail to rail inside the heads, and the dimensions will all be graduated down if a narrow gauge should be adopted. The standard slope for an earthwork fill is 1½ : 1, and for a rock fill 1 : 1, that is, 1½ ft. back or 1 ft. back for every foot in height.

Cuts should be 16 ft. wide at the base, and this will leave room at each side of the road bed for a 3-ft. drainage ditch. Care must be taken also that the cuts are wide enough to give ample clearance for any big plant that may have to be brought in, such as power skidders. The standard slope in earth cuts is again $1\frac{1}{2}:1$, but if the cut is in rock, the walls may be perpendicular. In spur lines cuts and fills are avoided as much as possible, as are drainage ditches, as the line is wanted in one place only for a very short time. If fills have to be made, the bottom is made up as much as possible with any handy timber which will not be saleable. This is covered with earth, and the sleepers laid on top (Fig. 76).

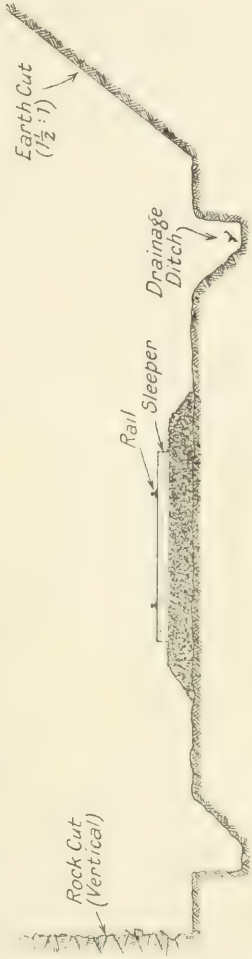

Fig. 76. Railway Roadbed, Showing Earth and Rock Cuts.

The simplest way of moving earth for railroad construction is by pick and shovel and wheelbarrow, or, instead of the latter, by horse or ox dump cart. For heavier construction there are various mechanical appliances for cutting and laying the road, such as steam shovels, scrapers, etc., but in laying a forest railroad these are unlikely to be available. If it is possible to obtain light rails or to make them from hardwood obtained from the forest, these should be laid on light unballasted sleepers temporarily, and shifted as required. A dump car to run on these rails with a capacity of two tons of earth or rock can easily be drawn for a considerable distance by one horse or a yoke of oxen. If the line is doubled or crossings laid where necessary, a number of cars can be used. As far as possible the earth or rock from a cut should be dumped at the nearest fill.

Drilling.

Before being moved, rock is drilled and blasted with dynamite. In placing the holes to be drilled in rock to be excavated, a rough rule is to place them as far apart as the depth to be taken out, but if placed closer, the rock is more broken up and is more easily and quickly removed and consequently more cheaply. Hand drilling does not require a high degree of skill. Holes of small diameter and up to about 3 ft. in depth may be made by one man with a hand drill, that is, he holds the drill in one hand and strikes it on the head with a $4\frac{1}{2}$ lb. hammer held in the other. The drill is of octagon steel, less in diameter than the size of the hole, with the cutting end hammered out to a chisel shape, the width of which is the diameter of the hole to be bored. A slight turn is given to the drill after every blow, this making the hole round. Drills after being hammered to the cutting edge must be very carefully tempered, after which the edge is finished on a grindstone.

The hole being drilled will fill up with the powdered rock, and this must be constantly removed or the drill will not cut. For this purpose a scraper is made of $\frac{3}{8}$ in. iron, long enough to get to the bottom of the hole. One end of the scraper is beaten flat and turned at right angles to the length. When the hole is getting choked with powdered rock, the latter is scraped up with the scraper.

For deeper holes two or more men do the drilling. One man sits down and holds the drill on the place to be bored, upright, sloping or horizontal, as the case may be. Another one or more men standing up strike the head of the drill in turn with heavy hammers, the holder giving the requisite slight turn after each stroke. The hole is begun with a short drill and longer drills are used as the depth increases. This style of drilling is suitable for holes up to about 8 ft. The usual sized octagon drill steel is $\frac{7}{8}$ in. and the chisel end $1\frac{1}{4}$ or $1\frac{1}{2}$ in. across, according to the size of the dynamite cartridge to be used.

For still deeper holes up to about 25 or 30 ft. and $2\frac{1}{2}$ in. diameter, a different style of drilling is used. A short drill is prepared and welded to the end of an iron rod several feet longer than the depth to be drilled. Different lengths are again used as the depth increases. This drill is sunk by lifting it and letting it fall on the spot to be drilled, giving the usual turn after each descent. It is customary for one man to drill in this way up to 3 ft. deep, while as many as four men are required for the deepest holes, according to the depth of the hole and the consequent weight of the drill. More than four men could not get at a drill.

Dynamite.

The explosives used are dynamite under one name or another. This is nitro-glycerine with an absorbent such as sawdust. The product looks like coarse brown sugar, and is not dissimilar in taste. It is packed in glazed paper cartridges, the commonest size being 1¼ in. by 8 in., containing ½ lb., but other sizes are obtainable. Cartridges are packed in sawdust in strong wooden boxes containing 25 or 50 lb. each.

Thawing Dynamite.

Dynamite freezes at a higher temperature than water, and if frozen must be thawed out before use. Men used to working dynamite become wonderfully careless in handling it and in thawing it. It is not uncommon to thaw it in an oven or near a fire in the camp, but this often leads to disaster and should never be permitted. The only safe way to thaw it is by gentle steam heat. A box can be made watertight by caulking the seams. Inside this is a smaller box with a lid to hold the dynamite to be thawed. The cartridges are placed in the inner watertight box and covered with the lid, the outer box is then filled with warm water and a lid put over the whole and the dynamite allowed to thaw gradually. The water should not be above 100° Fahrenheit, or the nitro-glycerine may separate from its absorbent. Dynamite is an inexplicable explosive and should never be jarred or handled roughly. In the case of an apparent misfire, no one should be allowed to approach the hole under 20 minutes from the time the shot should have gone off.

Destroying Dynamite.

Inferior dynamite deteriorates in warm weather, chemical decomposition taking place and often resulting in disastrous explosions. A greenish colour on the paper wrapping is a sure sign of decomposition, and handling such dynamite is dangerous. It should be destroyed as follows:

Cartridges are to be stripped, well spread out on waste paper or wood shavings, and sprinkled with paraffin.

The quantity of explosive to be destroyed at one time is not to exceed 5 lbs.

The explosive is to be spread out on the centre of the underlying layer of wood shavings or paper so as to avoid as far as possible any explosive remaining unburnt.

Any explosive found after the fire has burnt out is to be handled very carefully and completely destroyed in the next fire.

All fires are to be lighted from windward, using a small piece of cotton waste soaked in paraffin fastened to the end of an iron rod about 6 ft. long. As soon as the train is lighted the burners are to retire to windward to a safe distance, preferably taking cover.

Fires are not to be approached or interfered with until they have completely burnt out.

When a number of fires have to be burned in the course of a day, each fire must be placed to windward of and not less than 10 ft. distant from the preceding one.

Special care is to be taken to see that all explosive is thoroughly thawed before being burned. Under no circumstances is an attempt to be made to burn explosive while in a frozen condition.

Waste packets, packet wrappers and cartridge wrappers resulting from the stripping of explosives may be burnt separately, or may be used as the basis of a fire for burning waste explosive. Care, however, is to be exercised that such waste is free from any excessive admixture of loose explosive.

Dynamite of good quality may become dangerous if it has been stored under improper conditions. If the temperature of storage has been unsuitable, the nitro-glycerine may exude from the explosive and impregnate the wrapper. In this case it is quite unsafe to use, and must be destroyed.

Dynamite should be kept in a cool place in hot weather and a warm place in cold weather.

Blasting.

In charging a hole that is drilled, the cartridge should completely fill the round of the hole and require gentle but firm pressing in. If air spaces are left much of the force of the explosion is lost. A piece of safety fuse is attached to the top cartridge only ; if the hole is deep enough to need more than one cartridge, the others are pushed home, one by one, with a wooden rod, and when they are in place the top cartridge is prepared. A piece of safety fuse is cut off which will take long enough to burn to let everyone get out of danger. One end of this is inserted into the open end of the cap, which is a small copper tube open at one end and closed at the other with a charge of fulminate of mercury. The fuse is pushed into the open end till it touches the closed end, and is clamped in place by the open end of the copper cap being pressed into the fuse with a pair of circular nippers. The end of the cartridge is then opened up and a hole made in the dynamite with a stick like a lead pencil and the cap end of the fuse pushed into this. The fuse end of the cap should project a little out of the dynamite or the fuse may light the dynamite before it fires the cap. The paper ends of the cartridge are brought together round the fuse and tightened firmly with a piece of string. In pressing the top cartridge home care must be taken not to break the fuse (Fig. 30).

After the cartridges are in place the hole is tamped, that is, the rest of it is filled tightly with earth pressed or tamped in with a rod. This rod may be of copper, but never of any other metal, and the commonest is simply a wooden stick. A little earth or clay is put on the top of the cartridge and firmly pressed home. More is then added and tamped little by little till the tamping is about 6 in. deep. The hole is then filled up and the earth pressed firmly in to prevent any air spaces remaining.

Fuses are sold in coils and the rate of burning per minute is stated on the outside of the package, so that the length to allow for getting into safety can be known. When all is ready the free end of the fuse is lit with a match.

If it is desired for any reason to prevent fragments of rock from a blast from flying any distance, the blast may be smothered, that is, a heavy mat 6 or 8 ft. square, made of old 1½ or 2 in. rope, is put over the hole when it is charged. The explosion will throw this up in the air, but the open meshes of the mat allow the gases to escape gradually and fragments of rock will be kept down. If no rope mat is available, a good substitute is a pile of brush.

Trestles, culverts, and so on are constructed before the track is ready to lay. Trestles are used not only for bridging rivers, but for depressions over about 6 ft. in depth when this is found to be cheaper than filling, depending partly on the handiness of the timber to the spot. If a depression is trestled, the timber is taken down and used again after the road is finished with. Pile trestles are generally used in bridging streams when these are too wide for a span from bank to bank, and in swampy places, and when the track is along the steeply sloping side of a hill, so as to save deep excavation on the one side or extensive cribwork on the other.

Instructions for building trestle work are given in Chapter VIII. After the trestle bents are put in place, they are cut off at the predetermined height so as to bring the track into the proper grade line. The cut off marks must be made very carefully, and usually consist of nails driven into the trestle at a definite distance below the points at which the trestles are to be sawn off. The trestle is capped with a heavy timber 12 in. square, spiked to the top by spikes or drift-bolts 2 ft. long by 1 in. in diameter. In driving these heavy spikes auger holes are first bored slightly smaller than the bolts. Instead of the 12 in. cap, two 4 in. by 12 in. timbers are sometimes used, let into opposite sides of the top of the upright part of the trestle and bolted together.

On the caps are laid stringers running the same way as the rails. These stringers are of 14 in. by 8 in. sawn timber and are spiked to the caps. Two of these stringers are used to each rail, bolted together with washers between, leaving a space of 2 in. between each pair. On the stringers are laid the sleepers, 8 ft. by 8 in. by 6 in., every second sleeper being spiked to the stringers. The sleepers are spaced 24 in. from centre to centre. The distance from stringer to stringer is, of course, relative to the gauge. (See Fig. 74.)

Frame trestles instead of pile trestles are used where the ground is suitable. Instructions for building these are also given in Chapter VIII. The frame trestle bents should rest on mudsills, that is, planks of 4 ft. by 12 in. by 3 in., laid under the sills of the frame at right angles to them. Caps, stringers and sleepers are the same as on a pile trestle. The approaches to trestle bridges should if possible be dead level. If the trestle is on a curve, the outer rail of the curve must be elevated by cutting off the top of the trestle bents higher on one side than the other. Trestles on curves should be avoided if possible.

Swamp Road.

In building a spur line, if the ground is too swampy or soft for sleepers and it is not worth the expense of piling, a bottom for the road can be made of poles laid close together, the long way of the track. The sleepers are laid on the poles, spiked and ballasted. In very swampy ground, a bottom can be made by throwing in brush to a height of several feet above the intended level of the track. Sleepers are laid on the brush and the rails spiked down. A locomotive is taken slowly back and forward across this piece of track, which quickly settles down. A soft road may be corduroyed with poles 6 in. in diameter placed between each sleeper. These project far enough on each side of the track to get a hold on more or less solid ground. Poles for corduroy must be placed crosswise of the track, as although the track sinks when a heavy load is going over it, it then sinks evenly and comes up evenly and the cars do not leave the rails.

Culvert.

Rough culverts are made by placing a heavy log of the necessary diameter to get the height, crosswise of the track at each side of the stream to be crossed. Heavy slabs or poles are laid across from log to log and covered with brush to prevent ballast from falling through, and the sleepers are then spiked to the slabs.

Shifting Lines.

On spur lines which are frequently shifted, the sleepers wear out rapidly and replacement is a heavy item. This may be diminished to some extent by extra care when shifting the line, and by only spiking the rails to every other sleeper except at curves, where every sleeper must be spiked. When spur lines are being shifted and the rails lifted, only one spike in each end of the sleeper need be drawn, the inner spike of one rail and the outer one of the opposite rail on the same sleeper. The sleeper is then pried out of its place, leaving one spike still at each end of the sleeper. In re-laying the rail on this sleeper, the base of the rail is pushed in under the head of the spikes which remain. These spikes are then tightened up and the two others driven into their places. This lengthens the life of a sleeper. The constant drawing and respiking weaken it so much that it will often break under the rail.

Sleepers for a switch or turnout must be long enough to take the entire width of the double line at this point.

Standard gauge rails may be from 40 lb. per yard with a head $1\frac{7}{8}$ in. across to 75 lb. per yard with a head $2\frac{1}{2}$ in. across. Lighter rails are used for spur lines, as these have to be moved often and their lightness makes for easier handling, while they carry less traffic. The weight of the rails depends on the weight of the load to be carried and the distance between the sleepers.

Laying Rails.

Rails are spiked to sleepers with spikes of square iron, pointed at one end and with the other end turned over at

Fig. 77. Light Railway Engine.

[*By courtesy of "Sentinel" Waggon Works Ltd.*]

Fig. 78. Forest Railway and Log Cars : Poland.

[*To face p.* 108.

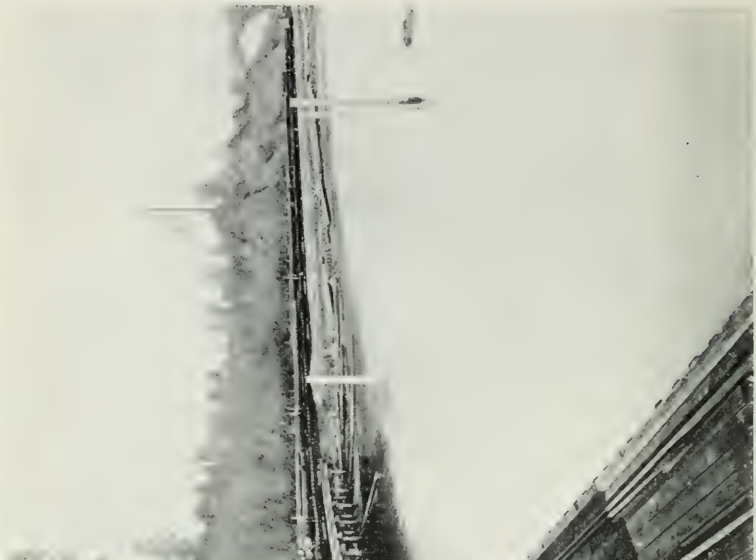

Fig. 79. Forest Railway with Log Train and Trestle Bridge.

[*By courtesy of Canadian Pacific Railway.*]

[*To face p.* 109.

right angles to grip the base of the rail. The rails are fastened together at the joints by fishplates. These are narrow iron plates having slots punched in them to correspond with holes bored through the web (the perpendicular part) of the rail. The holes in the fishplates are not quite round, but allow a little lateral movement, so that when the ends of the rails are bolted together, a small space can be left between them. This is necessary as the rails expand with heat, and if bolted close up against each other would buckle (Fig. 145).

The spur lines and any crossings or sidings are connected with the main line by a turnout consisting of a switch, a frog, and guard rails. Frogs of the required curve are supplied with the rails, but can be built up of separate rails cut as necessary. Rails can be bent to any curve by means of a " Jim Crow " or rail bender, a strong steel arch with a screw through the crown of the arch and two turnups at the ends to grip the rail to be bent. The rail is placed in these turnups and the screw worked down on to it by means of a bar. The pressure of the end of the screw on the rail bends the latter as required. The bend on a rail for a curve should not be abrupt, but the rail should be bent gently every foot or so, and if possible should not be bent at a joint.

When the switch and frog are in place, guard rails are spiked to the sleepers beside the frog inside the outer rails of both main and branch lines, leaving a 2 in. space between the guard rail and the carrying rail to take the flange of the wheel and guide the train to its proper line.

In laying a track, the sleepers, rails, spikes, fishplates, and bolts are loaded on a low flat car, and pushed either by man power or in front of a locomotive to the construction point. The sleepers are laid in position, the rails placed on them and joined by the fishplates being bolted in their places, when the rails are spiked to every other sleeper. The car is gradually pushed along as laying proceeds and a gang of men follow up and complete the spiking. On a straight part of a spur line the rail is not spiked to more than every second sleeper. On curves every sleeper is spiked. Four spikes are used to each sleeper, two to each rail, one inside and one outside.

Curves.

When a sharp curve occurs on the track, the gauge must be slightly widened to reduce the friction of the wheel flange against the rail and make it less likely to jump the track, the standard widening being $\frac{1}{16}$ in. for each $2\frac{1}{2}°$ of curvature over 5°. Further, the outer rail of a curve must be slightly elevated above the inner rail, the amount of elevation depending on the degree of the curve and the usual speed of the train at this point.

Gauging.

In laying the rails, the correct gauge is kept by an iron rod a little longer than the width of the track. The rod has a lug near each end at right angles to the rod, and the distance between the outside of the lugs is the gauge. The rod is laid across the rails when laying and the latter brought up against the outsides of the lugs.

To maintain the line, section men having one mile to look after on main lines and two miles on spur lines, keep in order the ballasting, gauging, clearing of drains, replacing of sleepers, and so on.

Fuels.

The fuel for the locomotives on forest railways may be wood, coal or oil. Wood is not very satisfactory, as with it it is difficult to maintain an even heat and a constant head of steam, and the continual expansion and contraction cause leaky tubes. It is consumed so quickly that a gang of men has to be constantly employed cutting it; much time is taken up by getting it on board, while it takes up considerable space, and a good deal of skill is required in stoking with it.

Coal is to be preferred to wood for various reasons, but may be too costly by the time it is brought in. At the same time steam is more easily maintained and with less labour than with wood. Both coal and wood are dangerous as

FIG. 80. LOADING LOGS WITH GINPOLE.

[By courtesy of British Columbia Government.

[To face p. 110.

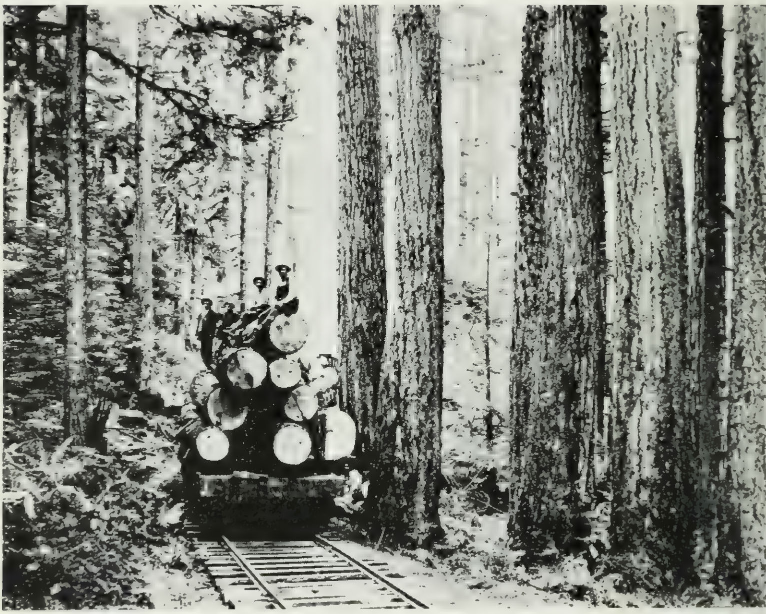

FIG. 81. LOADED LOG CAR ON FOREST RAILWAY: WESTERN CANADA.
[By courtesy of Canadian Government.]

[To face p. 111

liable to cause forest fires when used as locomotive fuel. Spark arresters must be used, and even they will not be entirely effective.

If oil can be obtained cheaply enough, it is by far the best fuel from every point of view. There is no danger from forest fires, the cost of putting it on board is practically negligible, while without any special skill it is easy to maintain a constant heat and head of steam.

Watering.

Provision must be made along the road at various points for watering the engines either from storage tank or flume.

Log Cars.

The cars used on logging railways are the ordinary flat cars, special logging skeleton cars and log trucks. Flat cars have wooden bunks across the floors at intervals to raise the logs off the floor and make slinging easier. (See Figs. 79 to 82).

An average skeleton car is 25 ft. long, having two four-wheeled trucks joined together by a heavy pole. The average truck has two wooden bunks, 8 to 10 ft. long and 11 ft. from centre to centre on which the logs rest.

A third variety of car is a truck for very long logs. It is a steel frame with two pairs of wheels. A crosswise steel swivel bunk, 9 ft. long, is mounted above the frame midway between the front and back wheels of the truck, and is furnished with spikes with the sharp points upwards to keep the logs from slipping backward or forward. A truck supports each end of the logs to be carried, and as trucks are not attached to each other they can be spaced any distance necessary. If the trucks are furnished with air brakes, which is advisable on steep grades, the rubber pipe for this is carried from one truck to the other under the load of logs, to one of which it is hung by ropes.

The amount of rolling stock required depends on the size of the timber operation, the distance to be hauled, the size of the timber itself, and so on. Allowance must be made for some of the plant being under repair, and all cars should be in multiples of three, one to be loading, one to be unloading, and one to be returning empty, as the railway will only be worked at the maximum profit when none of the plant is standing idle.

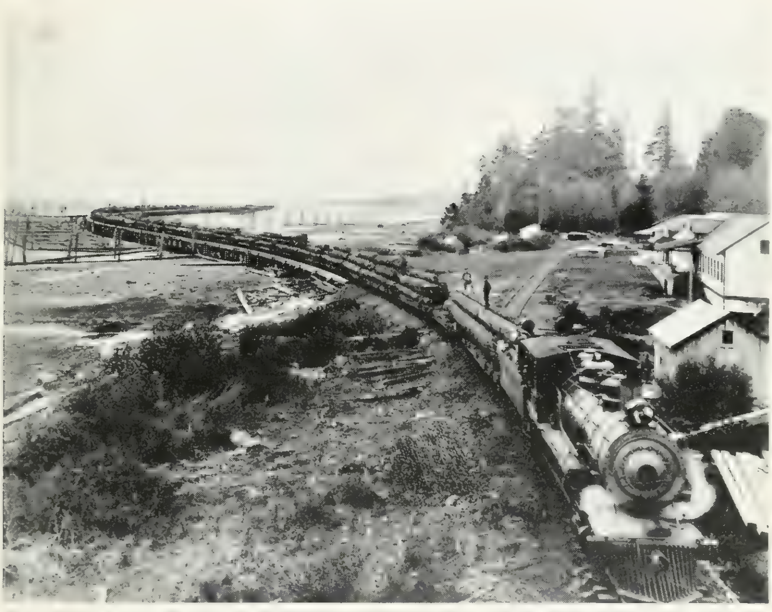

FIG. 82. LOG TRAIN ON PILE TRESTLES: BRITISH COLUMBIA.
[By courtesy of British Columbia Government.]

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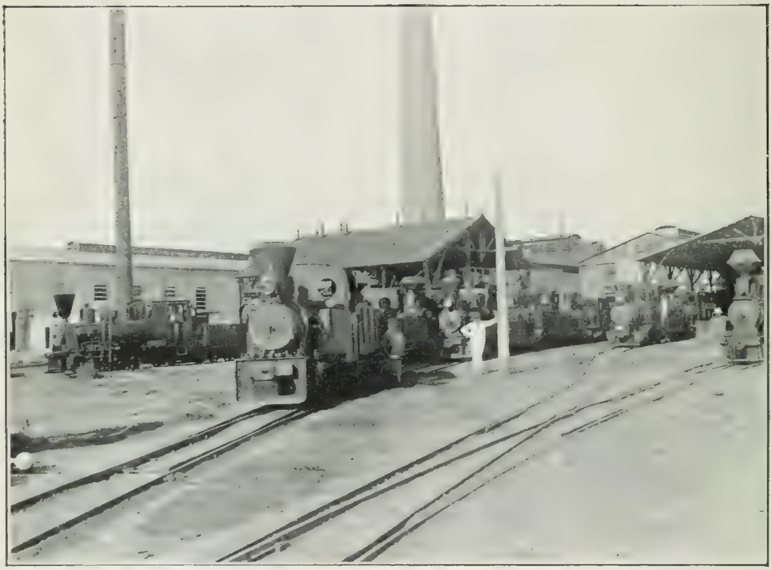

FIG. 83. FOREST RAILWAY AND QUEBRACHO FACTORY.
[By courtesy of Forestal Land, Timber and Railways Co., Ltd.]

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CHAPTER X

WATER TRANSPORT

River work—Removing obstacles—Booming—Construction of booms—Log sluice—Artificial channels—Dams—Sluice gates—Driving logs—Rafting logs.

As has been mentioned in a previous chapter, rivers have not as a rule the same volume of water at all seasons of the year, and depend for driving on flood water due to melting snows at their sources or heavy local seasonal rainfalls. Driving logs is, therefore, usually seasonal also and the operator has to have everything in readiness for the drive beforehand. If the logger misses the rise of the river or his logs get hung up in a jam, he may be held up for a whole year, and if dry seasons follow, for several years. In the meantime his capital is lying idle, his mill at a standstill, and his market missed. If this happens, when his logs do come down, they have lost much in value and in actual volume. Some loss, often a considerable one, will occur even at the best owing to logs sinking or stranding. In driving in very rough streams much of the timber gets badly knocked about and picks up large quantities of sand, gravel, and rocky splinters. These damage the saws at the mill and add very considerably to running expenses. It is to be remembered, too, that the cost of damming, booming, and otherwise improving a river is unlikely to be recovered directly. Logging improvements are of little use except to the logger, and as a rule are for purely temporary purposes. Taking into account all these disadvantages, the stream or river may still be the best or the only means by which logs can be economically brought out, and the cheapness of the actual working without heavy capital for expenditure on working plant in comparison with, say, a railroad, allows for a very considerable amount of loss in transit, and expenditure on improvements.

The stream must either be wide, deep, and straight enough to float the longest and biggest logs, or it must be made so.

The height to which water rises in flood time can be estimated from the drift wood on the banks left by former floods and from other indications.

Improving.

In carrying out stream improvements, fallen timber and snags are first cut up and allowed to float down stream, or are pulled ashore out of the way. Rocks and other obstructions which would cause a jam must be drilled and blasted when the water is low enough for the purpose. The method of doing this is fully described in the chapter on Forest Railway Construction, and applies to the removal of any rocks.

Booms.

Backwaters where logs would enter and remain, and low banks and shallows where they would strand, and any obstruction which cannot be removed, are boomed off. A boom is made of heavy logs fastened together end to end by heavy chains. These fastenings are of various kinds, but one of the handiest is the toggle and chain. A hole is bored right down through each log 1 ft. or more from the end. A heavy chain with a toggle on each end is passed through the hole in one log by pushing the toggle in endwise. The other toggle stops the chain when it comes up against the log. The end is passed down through the hole in the next log and the toggle opened out, and the chain is then held at both ends. It should be long enough to allow the logs to come from 1 ft. to 18 in. apart ; they should come far enough apart to allow for a certain amount of play but not far enough to permit the logs to work out between. When the boom is finished with, the toggle is brought back the reverse way and neither chain nor log is wasted. (See Fig. 84). Where necessary for strength, booms are doubled by having two similar booms side by side but not attached to each other. In booming a backwater, the boom is stretched across its mouth and anchored at each end by strong ropes or chains to convenient trees or stumps on the bank. If no convenient anchorage exists, stout posts for

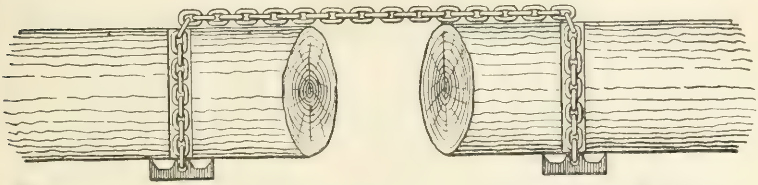

FIG. 84. TOGGLE AND CHAIN FASTENING.

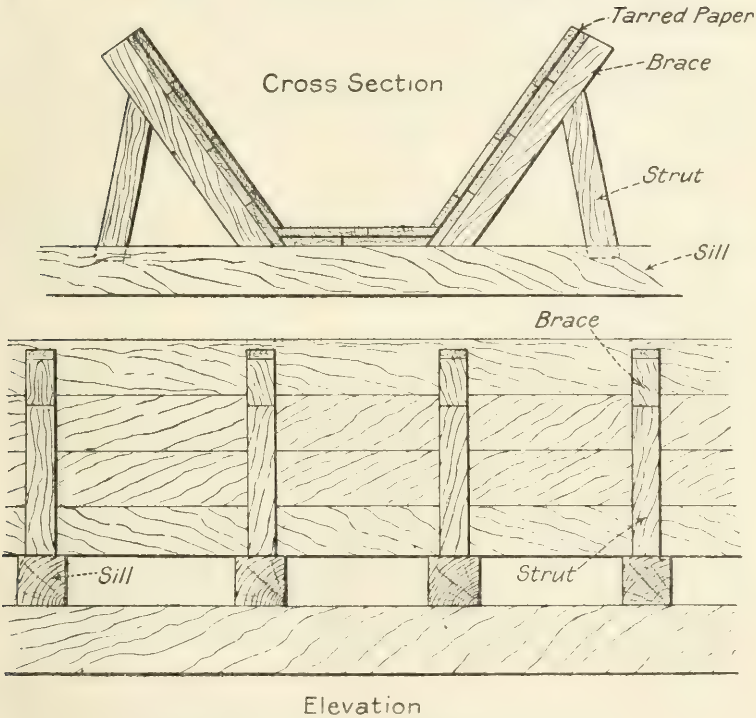

FIG. 85. LOG SLUICE. SCALE ¼ inch = 1 foot.

the purpose must be sunk in the ground to a considerable depth. The fastenings at the ends of the boom must be long enough to allow a considerable amount of play when the river rises or falls. If strained quite short when the river is full, they might be hung up in the air if the river should fall suddenly and would be useless. If low banks or shallows have to be boomed off, the ends of the boom must be moored to anchorages in the stream and on the bank or to anchorages in the stream only as the location may be wanted. An anchorage in stream may be constructed of cribwork filled with stones to keep it in place.

Another kind of boom which is used when necessary to slant logs into the sluiceway of a dam or into a log sluice is the bracket boom. It is constructed in the same way by logs joined end to end with chains, but is made several logs wide and these logs are connected by boards or poles nailed across them, which not only serve to keep the boom stiff but also give footing to the men who are guiding the logs there. The joints of the parallel logs on a bracket boom should not coincide.

Stretches may occur in a rough stream which cannot be improved by booms or blasting, or where enough water cannot be obtained to cover deeply the natural channel, or where there is a dangerous rapid or some other obstacle impossible to overcome.

In such a case it may be possible to instal a log sluice to carry the logs past these sections, having its exit from the stream at steady water above the obstacle and its re-entry lower down, when the use of the river is continued.

Log Sluice.

A log sluice is not made "V" shape like the flume, but is constructed with a bottom and two sides, each of the latter forming a wide angle with the bottom. All the supporting construction must be stronger than with flumes, as the log sluice is larger and carries a greater weight of water.

It is built of two thicknesses of 2 in. plank, preferably with a layer of tarred paper between, and the outer planks break joint with the inner. Fig. 85 shows a cross section of the sluice. The gate is constructed at the head of the sluice in the same way as the gates for the dam sluice which are described further on, but it need not be of such heavy construction. It is only opened when logs are being sent down. It should be as far as possible constructed on the ground, but a certain amount of cutting and filling will probably be necessary. It is, however, much less costly as a rule than the cutting of a canal would be, but if the ground should be specially suitable for the latter owing to some local condition, then the canal would be excavated and the log sluice would be unnecessary.

Artificial Channel.

If the river should widen out suddenly to a considerable distance and the depth of water be quite insufficient for driving, instead of a log sluice being built, the water may be confined between one bank and an artificial bank made of cribwork.

The cribwork wall may be prepared ashore in sections and floated out as its construction proceeds. The width of its base will depend on the height to which it is to rise, but the angle of the inner face of the wall, which holds up the water when finished, should be about 45°. Fig. 86 shows the construction. Parallel lines of logs are laid down on the bank running the way of the stream at a distance of about 8 ft. apart, the number of lines depending on the width of the base. On these are laid a series of logs at right angles, also about 8 ft. apart, and notched and spiked where they cross the under ones. On these, again, logs are spiked, running the same way as the bottom logs, and the wall is gradually built up as high as necessary, carrying the inner face back tier by tier as it is heightened, as shown in the sketch. It can be floated out gradually as it grows. Decks of poles are placed across the logs in the lower part of the crib, and when the latter reaches the bed intended for it, rocks are piled in to sink it and keep it in place. Other sections are constructed, floated out, and sunk in the same way, until the framework of the whole wall is in place. Poles are now nailed at intervals from top to bottom of the inner face, to which stout horizontal planking is nailed, and the wall is complete. A deep channel will now run between one bank of the river and the crib wall.

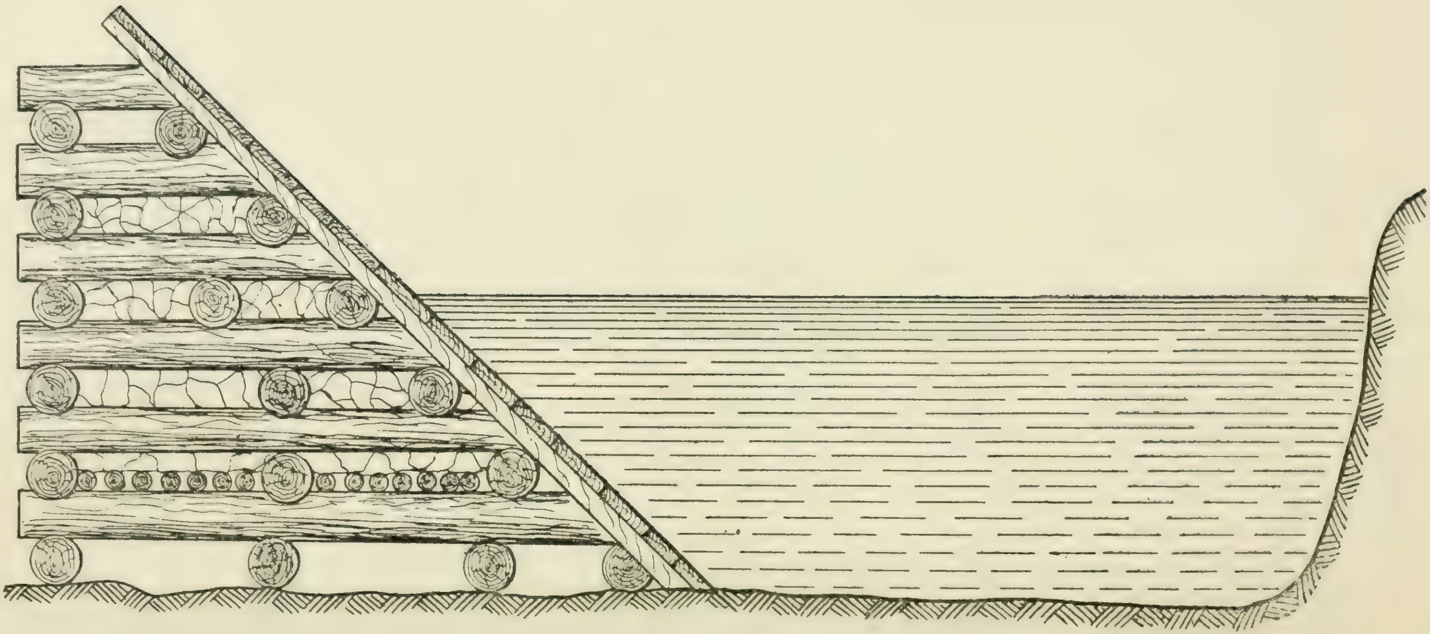

Fig. 86. Cribwork Bank Creating Artificial Driving Channel.

To protect the banks of streams during flood time and prevent them being worn away, a cribwork wall of similar construction can be built into the bank. It need not be faced with planking, but the crib is filled entirely with rocks.

Crib Dams.

Dams for logging purposes are built of round timber. The foundation must rest solid on the bed of the river, or sooner or later the dam will be carried away. The work of dam building must, of course, be done when the water is low, and even then it will probably be necessary to divert the stream into a temporary channel, which can be done well enough to suit the purpose by means of sandbags.

There are various types of dams, the simplest being made so that logs will go right over the top of it. Or it may be a more elaborate structure with a sluice for passing the logs through, and smaller sluices for running off surplus water. This last will be necessary if it is intended to hold up the water altogether at times and drive the river in sections.

If the river is one in which much ice forms in winter and comes down in large masses in spring, the upper face of the dam should not be perpendicular, or the ice may jam and pile up at that particular point, holding up an immense weight of water and ice behind it which, when released, may carry away the dam as well as the ice. In this case also any headworks for lifting the sluice gates should be capable of removal before the river freezes up, as otherwise they are quite certain to be carried away when the ice goes out. The construction of a dam in such a river will be indicated.

A timber dam is not usually piled, but is constructed of cribwork. Should it not be possible, however, to rest it on bedrock, piles may be driven to bedrock or into a good stiff clay, and the bottom logs of the crib bolted to these. If resting on the bed of the river, trenches are dug in the bottom several feet wide in which to lay the lowest logs or mudsills. This foundation is excavated slightly convex on the upstream side, as when the dam is built in this shape the pressure of the water held up will help to tighten all the joints.

The width of a dam at its base is roughly the same as its height when finished.

Sluiceway.

The mudsills are logs of about $1\frac{1}{2}$ ft. in diameter. They are laid in parallel lines across the bed of the stream in the trenches or on the piles, and let well into the banks at both sides. If on bedrock, holes should be drilled into the rock and the mudsills anchored to it with 1 in. bolts, as this all helps to strengthen the dam. The number of lines of mudsills will depend on the width the base of the dam is to be. The mudsills are laid 7 ft. apart. A row of cross logs is now laid on the mudsills, these logs being about 1 ft. in diameter and stretching right from front to back of the mudsills. The front of the dam is the downstream side and the back is the upstream side. They are laid at the same distance apart—7 ft.—and are notched where they cross the mudsills, to which they are spiked with $\frac{3}{4}$ in. iron spikes. Then logs of similar size are laid on the cross logs, right over the mudsills, notched and spiked as before, and the dam is built up in this way till the water level is reached. It will now be a length of cribwork with cribs 7 ft. square. From the stream level the cribwork is continued upwards without a break if it is not intended to have a sluice. If it should be a sluice dam, however, the crib work above the stream level is continued at the sides, but leaving a space in the middle of 10 to 15 ft. for the sluiceway. If the dam is to hold up a very heavy head of water, smaller openings should be left for waste gates between the sluiceway and the banks on both sides. They are constructed in the same way as the sluice, and are for the purpose of allowing surplus flood water to escape. The sides of the sluiceway and of the waste gates are constructed more strongly and of heavier logs than the rest of the dam, as they both carry headworks.

At the bottom of the sluiceway and wasteways the transverse logs are cut off. The walls of these have hewed faces and fit closely together. The whole of the cribs should now have decks of poles rested on two sides of each crib. These decks should be at intervals of 5 or 6 ft. above one another, and each deck should be well filled with rocks. If only one deck is put into the cribs at the bottom and filled with rocks, the floating power of the water tends to lift the upper timber work off the lower, the drift bolts or spikes get loosened, and the whole dam may come to pieces. If, on the other hand, the deck is too high up, the crib would be top heavy and the dam might topple over.

The upstream face of the dam is now boarded with 3 in. planks to make it tight. If the dam is not resting on bed-rock, a row of small hewed poles close together is driven into the bottom of the river bed across the stream just in front of the farthest upstream mudsill. This helps to prevent water getting under the dam.

If it is a sluice dam, sluice gates must be erected to be opened when logs are passing through, and shut down again to increase the depth of water in the stretch above the dam. There are various kinds of gates, but one of the simplest and most effective and most useful is the ordinary lift gate. The floor of the sluice is constructed of heavy square hewed timbers the same as the sides, and is continued along with the sides some little way out from the lower face of the dam to throw the logs clear of the latter, which they would otherwise damage.

Sluice Gate.

The gate of the sluice is of hardwood 2 in. thick, and wide enough to rise and fall easily in the slides which hold it at each side of the sluiceway. The frame of the gate should be of 6 in. square hardwood and the transverse planks mortised into this, and the whole strengthened with 2 in. thick strips nailed diagonally on both sides from corner to corner of the frame. These strips are also nailed to the transverse planks.

The slides are made by cutting a deep notch in the logs forming each side of the sluice from top to bottom near the entrance to the sluiceway, and the notch should gradually widen out from the bottom to the top. At each side of each notch is nailed a hardwood strip 6 in. square. The space between two strips at each side is the groove in which the sluice gate runs, and must be wide enough for it to run freely when raised or lowered (Figs. 87 and 88).

The slide strips should extend about 6 ft. above the top of the dam so that the gate will still keep in place when raised above it, and remain in position to lower at once. The gate can either be raised by simple leverage or by a hand winch which winds ropes passed through blocks on the head gear and hooked to eyelets bolted on the top of the gate.

Ice Precautions.

In the case of a river in which heavy ice forms in winter, however, if a sluiceway has been constructed, any slides or head gear above the top of the dam should be screwbolted to the timbers of the latter instead of spiked, so that they can be taken down when ice forms, and replaced after the river is clear.

If the river is one in which heavy ice forms, it is better that the back of the dam should not be perpendicular. When building it, and before the water level is reached, the construction of the upstream face should be continued inwards at an angle of 3 horizontal to 1 vertical, and the top of the dam should not be less than 10 ft. wide. When the cribwork is finished, a row of 6 in. hewed poles close to each other is spiked up and down on the sloping upstream face. This sloping face, as well as the upright face of 3 in. planking already described on the previous dam, can be caulked with tarred tow to make the face perfectly watertight. The sloping face will carry floating ice over the dam without injuring the latter.

Driving.

Before the drive begins, provision must be made at the bottom of the stream for catching the logs as they come down. If they empty into a lake or arm of the sea, or if they are to be stopped at a steady part of the river where the mill may possibly be situated, an impounding boom is stretched across the river. It is set in a wide curve with an end anchored to each bank. If desired, a second boom

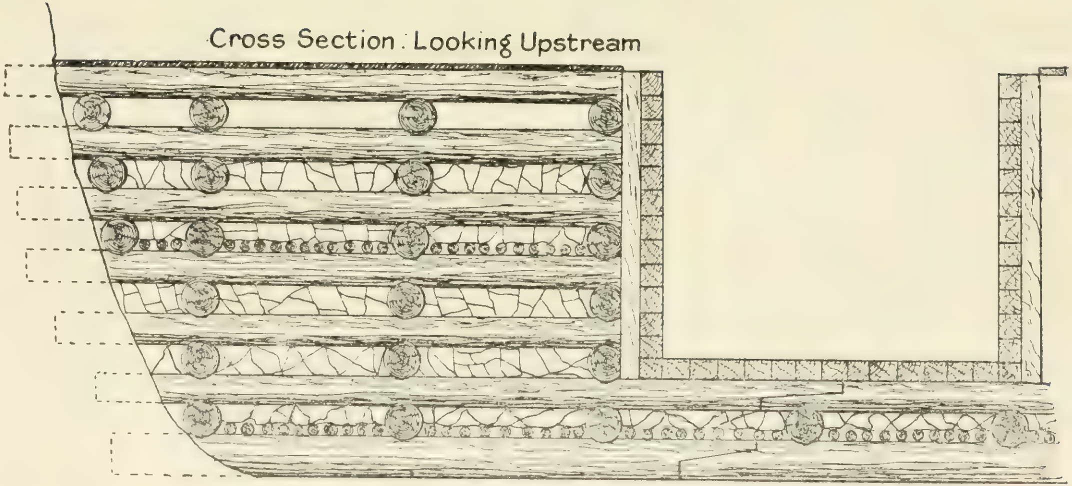

FIG. 87. CRIBWORK DAM AND SLUICEWAY. SCALE $\frac{1}{8}$ inch = 1 foot.

can be anchored parallel with the first one but not attached to it. If any logs work under the first boom or if this boom gives way, the logs will be caught by the lower one.

Banking.

For driving, logs are banked at various points along the river till the season's cut is all out or till there are sufficient logs to make a drive, or possibly until there is sufficient water in the river for driving, either naturally or accumulated by a dam. When all is ready, the bank or stack of logs is broken by a gang of men rolling them into the river and starting them off. If the river has been frozen, the logs may have been placed on the ice with which they go down when the river opens (Fig. 89). The work of driving is begun at the stack lowest down the river and gradually comes up. If sluice dams are in use, the sluices are opened a short time before the first log is started and kept open till the same length of time has elapsed after the last log has gone through. If this is not done, jams will result. Men are in readiness at each sluice with pike poles to pass the running logs through and prevent jamming, and also at each point on the river where jamming or stranding looks possible. It is essential to keep the logs moving. If a jam is imminent, the logs may be loosened if taken in time by the dog warp. This is a rope stretched right across the stream having two strong hooks in the middle. The hooks are caught into the logs and men pull on each end of the rope from the banks alternately, probably loosening the logs. If a bad jam results, it is often impossible to loosen it in any other way than blasting it with dynamite, but this course is to be avoided if possible owing to the damage done.

After all the logs are in the water, a gang of men begins at the top of the drive on each bank and works down, putting into the water any logs which have been stranded from the main drive and clearing the river completely as they go.

Rafting.

On a deep river with slow current or on lakes or tide-

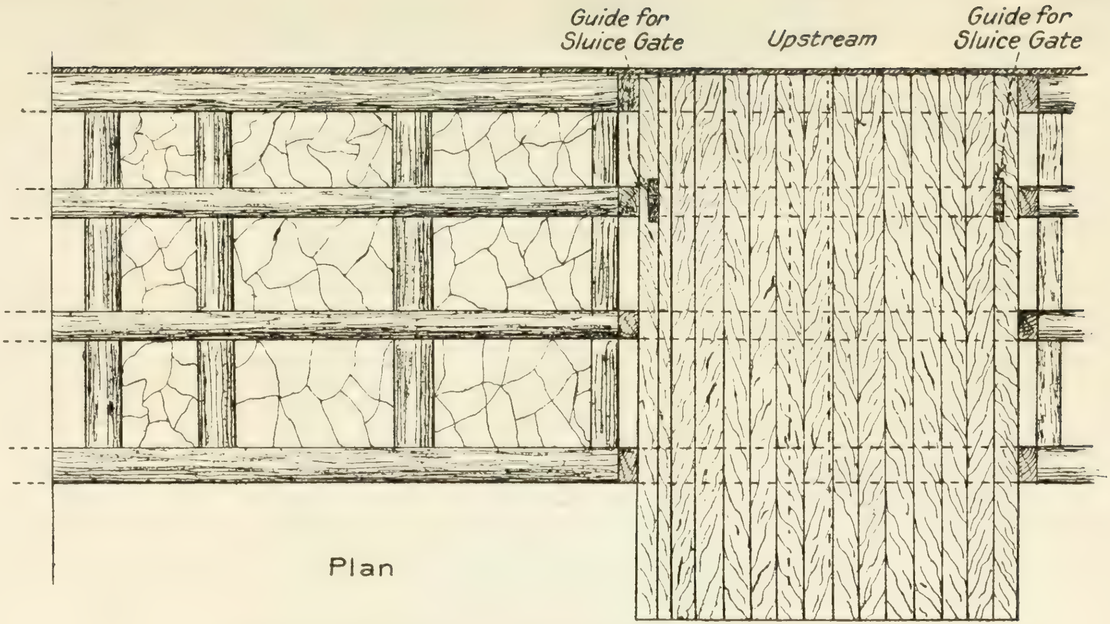

FIG. 88. CRIBWORK DAM AND SLUICEWAY. SCALE $\frac{1}{8}$ inch = 1 foot.

water, logs can be rafted instead of driven, while the driven logs are also rafted after they enter calm water. They may be towed loose inside the impounding boom by closing the two ends of the boom when there are enough logs inside to fill it. A tow line is then made fast from the boom to the motor boat, steam tug, or whatever the motive power is, and when the boom is towed along the logs inside come with it. A boom for towing in this way is best to be of short logs of big diameter—the shortness to make it handy for drawing close and the big diameter to prevent the towed logs from working underneath. If there is any lop on the water, that is, a slight swell, watch must be kept that the logs do not work their way out under the boom. If there was much of a swell, this would happen continually and therefore towing must be done in calm weather (Fig. 95).

Logs may be rafted and towed if in steady water and this has the advantage that those that will not float can be made fast to others that do.

The simplest way of rafting logs is to bring them side by side, butts all pointing ahead. A manilla or coir rope is made fast to the butt end of the first log, passed round the butt of the next log with a half hitch, then round the next, and so on to the farthest out log, the rope being tightened up at each one. If the logs tend to roll in towing, one is apt to slip out of the half hitch and, as this would slacken the rope, would give the other logs the chance to follow suit. To guard against this, an auger hole can be bored a short way into the end of each log near the butt, a short wooden pin driven in, and the half hitch made behind the pin, when it will not slip off.

A more secure way for towing long distances is to fasten the logs together side by side with poles at intervals across the top, thus making a perfectly stiff raft. The poles are fastened to the logs they cross by hardwood pins driven down into auger holes bored through them and into the logs. Or the poles may be fastened to the logs with dogs, each dog consisting of two iron spikes, the heads of which are connected by a short chain. A spike is driven into the log on each side of the pole, the chain going over the pole and

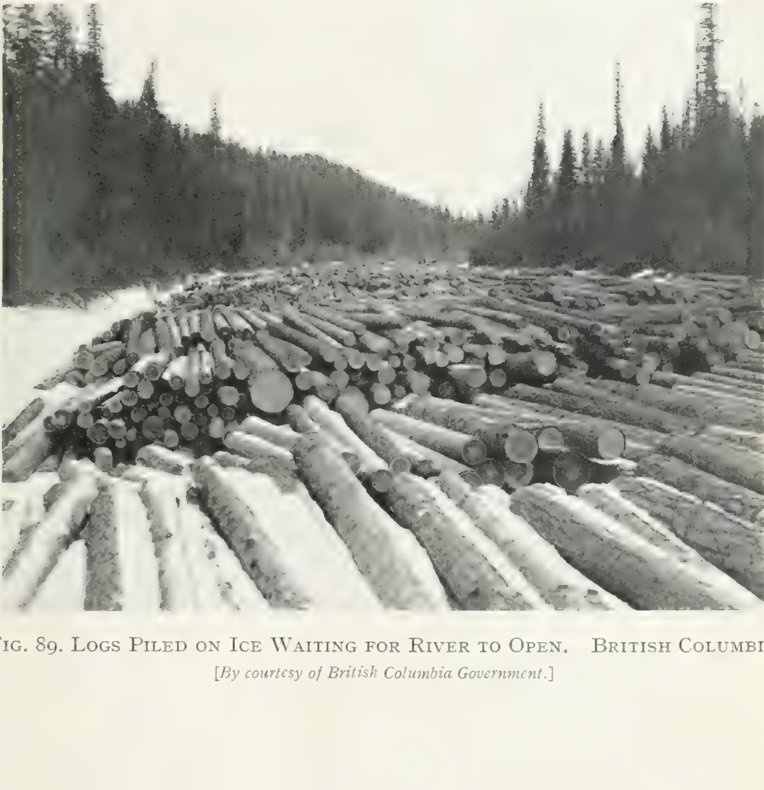

FIG. 89. LOGS PILED ON ICE WAITING FOR RIVER TO OPEN. BRITISH COLUMBIA.
[By courtesy of British Columbia Government.]

[*To face p.* 126.

Fig. 90. Driving Logs: Canada.
[By courtesy of C.P. Railway.]

To face next plate.

FIG. 91. DRIVING LOGS: NEWFOUNDLAND.

FIG. 92. LOG DRIVE WITH JAM IN DISTANCE: CANADA.
[*By courtesy of C.P. Railway.*]

[*To face last plate*

Fig. 93. Cleaning up Log Jam: Newfoundland.

Fig. 94. Rolling Logs into River: Poland.

[*To face next plate.*

Fig. 95. Motor Boat Towing Logs Enclosed in Boom: Newfoundland.

Fig. 96. Building Log Raft: Poland.

[By courtesy of Century Timber Corporation.]

[To face last plate.

Fig. 97. Log Raft Floating Down River: Poland.
[*By courtesy of Century Timber Corporation.*]

Fig. 98. Log Raft Arrived at Mill: British Columbia.
[*By courtesy of Canadian Government.*]

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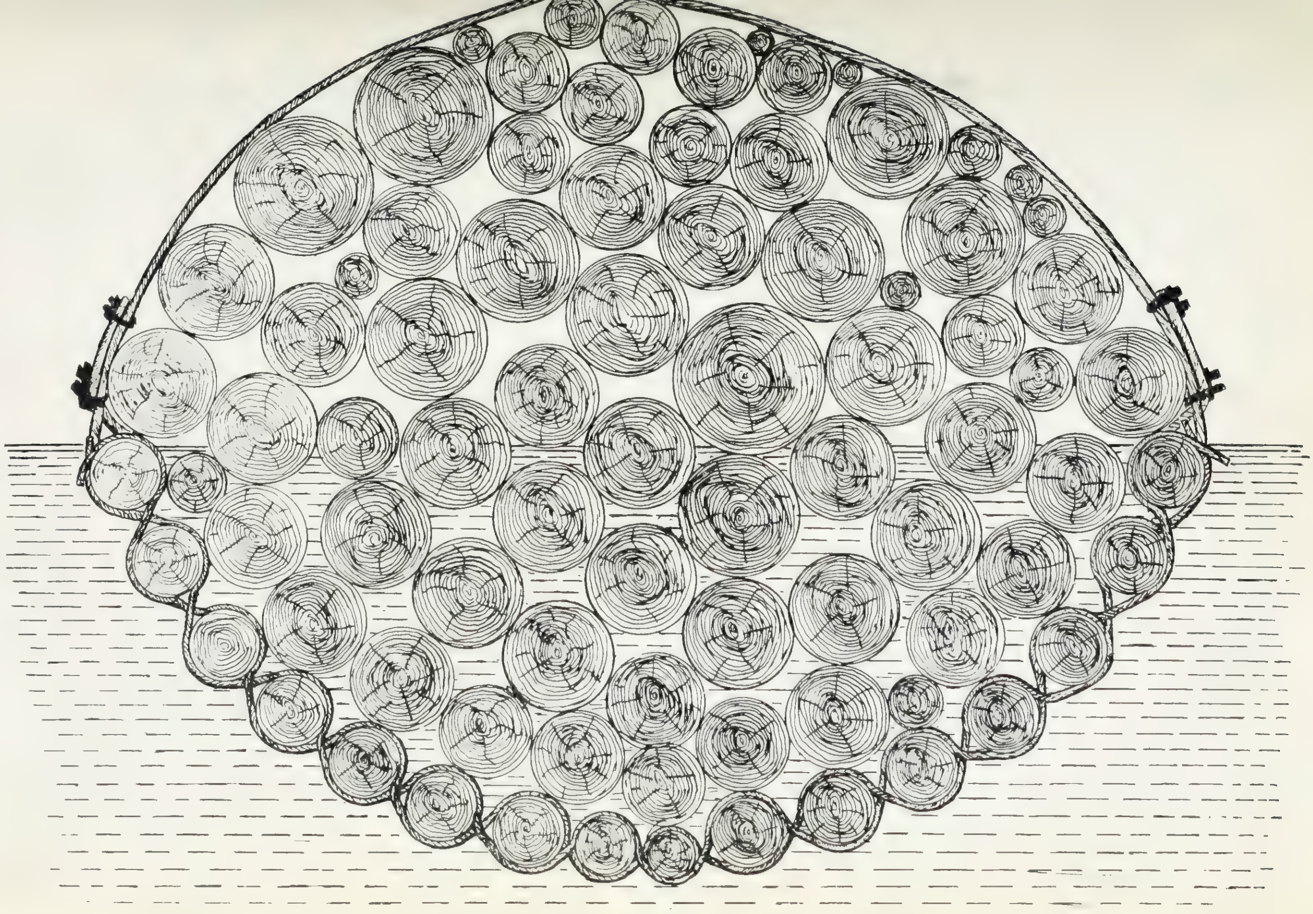

Fig. 99. Sea-going Log Raft: Cross Section.

FIG. 100. BUILDING SEA-GOING LOG RAFT: BRITISH COLUMBIA.
[*By courtesy of Canadian Government.*]

[*To face p.* 127.

keeping it in its place. When the raft is broken up, the dogs are pulled out and may be used indefinitely. A raft of this kind may be about 20 to 30 ft. wide, and can have several sections towed behind it, made up in the same way. Men help to keep such a raft on its course by means of long oars or sweeps, and as many as a thousand logs can be towed at one time (Figs. 96, 97, 98).

Logs which will not float may be bundled with logs which will or with bamboos into one raft. Two old wire ropes are used as a kind of cradle, laid on the beach at low water or in shallow water if there is no tide. The ropes are distant from each other a little less than the shortest log to be bundled. Logs floating and otherwise are built up on each other into roughly a cigar shape, and the ends of the wire ropes brought together and tightened up firmly by means of a hand winch. Strong chains are then bound round each end of the raft and firmly fastened, and the raft is ready for towing. It is pushed off bit by bit as it is built up.

Sea-going Rafts.

Enormous rafts of logs are built for transport by sea. If such a raft be constructed at tide water it can be built up at low water on the beach and moved off into deeper water as it grows.

A boom is made to enclose a rectangular space the size of the finished raft, say, 150 ft. by 75 ft. The boom must be anchored at each of the four corners to keep it in shape. or temporary cross pieces spiked to its corners for the same purpose. The logs to be rafted are now floated or lowered into the boom and placed side by side with the butts in the centre. These logs form the floor of the raft and fill up the entire space. They are fastened together at intervals with two $1\frac{1}{4}$ in. chains criss-crossed, so that a chain goes round the top half of one log and the bottom half of the next, the other chain going the reverse way. (See Figs. 99 and 100.)

The ends of the chains are tightened up and made fast to the outside boom logs. Tiers of logs are now piled up regularly. Heavy chains are passed under them, tightened up and made fast to the boom logs. In building up, the raft is gradually narrowed. When half the logs are laid, a heavy towing chain is laid right along the centre from stem to stern, projecting 50 ft. beyond each end of the raft. When all the logs have been loaded, binder chains are passed over those above water and made fast to the side boom logs. With the butts all being in the centre, the raft tapers to both ends, and when the chains are tightened will take roughly the shape of a cigar. Heavy chains are now attached to the forward end of the towing chain where it enters the raft and passed aft, and attached to the corresponding after end of the towing chain, being made fast also to the binder chains where they cross.

Logs may be of unequal lengths, but all joints should be broken so as to make the raft stiff. The towing chain, having the longitudinal chains attached, distributes the strain of the tow over the whole raft instead of its coming all on one point. The raft is now ready for towing to its destination.

Crib Pier.

A wharf or pier may be built of cribwork of any size required. The pier shown in Fig. 102 was built to reach out to deep water. Cribs were made of logs in the manner already described. Each crib was about 10 ft. square and was built up on the beach, and floated out as it grew in height. It was then sunk in its allotted place with a deck of poles, which was loaded up with rocks. The cribs were sunk about 12 ft. apart in a straight line. Poles about 6 in. in diameter were then laid across from crib to crib so as to form two lines of stringers from the shore to the outside end of the pier and spiked to the top logs of the cribs. A deck of rough hewn planks about 3 in. thick was then nailed from end to end on the stringers. The head of the pier was widened out, and accommodated vessels drawing 20 ft. of water.

The same kind of wharf can be built for much larger vessels by simply extending the cribs and making the work

Fig. 101. Log Jam: Western Canada.
[*By courtesy of C.P. Railway.*]

Fig. 102. Stacked Sawn Pit Wood, Crib Pier and Motor Towing Boat: Newfoundland.

[*To face p.* 129.

heavier and using logs of greater dimensions. It should be built hammer headed in shape—the head for the vessel to lie against being much wider than the gangway from the shore end to the head. The gangway need only be wide enough to accommodate two sets of rails if loading is to be from railway cars.

On the front of the wharf, against which the vessel lies, poles 6 in. in diameter should be spiked close together perpendicularly from below low tidemark to the top of the wharf. When the front of the wharf is being built up, a log of about 18 in. in diameter is spiked strongly inside the cribs at each end and near the front of the wharf. It stands perpendicularly, and extends 4 ft. above the wharf deck. Heavy rocks are piled round it to the top, and the deck planking is fitted round it. These two upright logs form bollards, to which the vessel's hawsers are made fast, to tie her up to the wharf.

CHAPTER XI

PERMANENT BUILDINGS.

Building construction—Preservation of timber—Provisional housing—Buildings of logs, sawn lumber, pisé de terre, bricks—Making bricks—Burning lime—Wells—Housing equipment—Sanitation—Hygiene.

In house building in the forest, the material which is most easily obtained is simply the log itself. Buildings of logs are particularly suitable for northern latitudes or for high altitudes in hot climates, but naturally not so suitable where the white ant and other pests exist. They are possibly the easiest of all buildings to construct and necessitate least outside material.

Log Camp.

While the construction of permanent housing, staff buildings, mills, etc., is going on, it is necessary to have a temporary camp. This is to be preferred to living in a tent while lengthy operations are proceeding. In cold countries, and even elsewhere for short periods, the most comfortable camp is the log hut. It is very easily constructed and with practically only the material in the forest. It need only be of one room or two at the most. A space is cleared and roughly levelled large enough to accommodate whatever kind of hut may be wanted. Four logs, 1 ft. to 18 in. in diameter, are laid on the ground for the sills, one each for the front and the back and one at each end in the shape of a rectangle. These are notched into each other about 6 in. from each end so that the tops are level, and the upper faces are roughly hewed flat. The walls are now built up of similar logs unhewed. These are placed above the sills and notched into each other, so as to allow the logs practically to touch all along. No nail or spike is required as the deep notching holds all the logs

Fig. 103. Log Hut in Summer: Northern Canada.

Fig. 104. Log Hut in Winter: Northern Canada.

[*To face p.* 130.

Fig. 105. Log House: Newfoundland.

Fig. 106. Log House: Newfoundland.

[*To face p.* 131.

in their place. An opening is left for doorway and windows, and a rough framework made for these of hewed poles. When the height all round has been reached, the end logs are shortened gradually till they come to a point, so as to make a gable, giving the necessary pitch to the roof. This is done by nailing on the outside of the middle of each end wall a stout pole, forked at the top if possible, reaching about 3 ft. above the walls. To these poles the shortened end logs are nailed. A ridge pole is now fastened in the fork to form the peak of the roof, and the roof, itself of poles, which need not be close together, is now nailed from ridge pole to eave, covering the whole building. The covering of the roof can be made from the bark of trees, which in the meantime has been stripped in sheets and flattened on the ground with poles on the top of it to keep it in shape. These sheets of bark are now placed on the roof in the same manner as slates. giving each upper course an overlap of several inches over the lower one. When the roof is covered, poles are laid at intervals again from ridge pole to eave on the top of the bark to keep it in place. These poles project several inches above the peak, and crossing each other every pair forms a fork. In this fork is laid a heavy pole, and this will keep the roof in place no matter what storm may be raging. All these details can be seen in Figs. 103 and 104, which show one of these log huts, which was lived in and made the head-quarters for a considerable operation for several years, without showing the slightest sign of deterioration. The floor can be made either from sawn lumber or hewed poles nailed close together from sill to sill. The cracks between the logs are "stogged" or caulked with dry moss pushed hard in, and the dwelling will be perfectly comfortable and wind and watertight both in summer and winter.

Log House.

For a more permanent dwelling of logs in a suitable country, the site should be chosen in thick woods and not in an exposed situation. When the thermometer falls considerably below zero and there is a high wind blowing, the cold is severely felt in the open, while with the same temperature in thick woods it is not noticeable. The site should be near running water, and marshy ground should be avoided.

The log house whose actual construction is here described is shown in Figs. 105 and 106 and was built entirely with unskilled labour. It was designed for the principal permanent residence of the manager of a considerable wood pulp industry during construction.

A space was cleared about 70 ft. by 40 ft. in a little birch wood on the bank of a river. The sills were laid on the surface as described in the construction of the log hut, but were of logs of 18 in. diameter with the upper face hewed flat, and these formed the foundation. All the logs used in the construction of this house were barked, and were hewed flat on two sides so as to allow each log to rest entirely on the one under it. The sills for the front and back were 45 ft. long, and each sill was made up of two logs scarf-jointed and fitted end to end. The end sills were about 16 ft. long and were laid across the front and back ones, being notched where they crossed, leaving about 6 in. of each log projecting.

The logs chosen had as little taper as possible, and where necessary for length were scarf-jointed end to end. The walls were now built up of these logs so that the flattened faces came together, and were carried to a height of about 8 ft., leaving a space for a door in the middle of the front wall and another near one end of the back wall in the kitchen part. Spaces were also left for windows, and the door and window frames were formed of hewed poles nailed in place.

When the walls had reached the desired height, they were continued at each end in the form of a gable, the logs being shortened as they rose and spiked to each other. The peak of the gable was about 4 ft. above the front and back walls so as to give the necessary pitch to the roof.

The interior was divided by two partitions of hewed poles into three apartments, the living room in the middle, 16 ft. by 14 ft., to which a door entered directly from the outside, the kitchen on the left, 12 ft. by 14 ft., and the bedroom on the right, 14 ft. by 14 ft. Doorways were left in these partitions and frames of hewed poles nailed in place. On the top of each partition a stout hewed tie post was nailed across from the top of the front wall to the back. In the middle of each was nailed a king post to support the ridge piece. A string was now tied from the peak of one gable to the peak of the other and the king posts sawn to the same height.

The ridge piece, made up of two lengths of hewed poles, scarf-jointed, was now nailed from the top of one gable to the other and to the two intermediate king posts, and rafters of hewed poles were nailed at intervals of 18 in. from end to end of the house, resting at back and front on the ridge piece at one end and at the other on the top logs of the walls.

Joists of poles hewed on the upper and lower faces were now nailed at intervals of 1 ft. inside the house from front to back sill. The flattened faces of the sills projected far enough beyond the smaller wall logs to give hold to the ends of the joists. Floor boards were nailed on the joists from end to end and the partitions were also covered with boarding. In the kitchen floor a square was cut out and a trap door fitted in. Underneath, a hole was dug and floored and lined with boards to serve as a cellar in which eatables were kept cool in summer and from being frozen in winter. Rough boards were now nailed to the rafters to form the roof, the lowest board on each side projecting several inches over the walls to carry off rain or snow.

Over the whole of the roof, tarred roofing paper was fastened with flat-headed roofing nails, beginning along the lower edge of the roof at each side and giving each sheet of the paper an overlap of 4 in. on the top of the lower one. Laths at intervals of 2 ft. were nailed over the roofing paper from the ridge to the eave, to prevent the paper being lifted by any wind. A pole was then fitted along the peak of the roof and nailed over the paper and laths, and the entire roof was given a coat of tar. A roof of this kind, well tarred every second year, will last indefinitely.

Doors of dressed boards were hung in their places, and window frames which opened on hinges put in place and glazed. The inside of the walls was lined with roughly dressed boards. The cracks between the logs of the walls were "stogged" from the outside with dry moss.

In the kitchen a square of sheet iron was nailed on the floor and a cooking stove for burning wood was set on it. The best kind of stove for the purpose is the type of the "Columbia." The chimney was of thin sheet iron pipe, which passed through a hole cut in the roof, 4 in. greater in diameter than the pipe. To cover this hole and keep out wet, a piece of tin was nailed under the tarred paper with a hole just big enough to let the pipe through. A small anthracite stove was similarly fitted in the living-room and another in the bedroom, but the house was found to be so warm even in winter with the thermometer 20 below zero that the bedroom stove was dispensed with. During the winter snow was piled up round the walls of the house to a height of 1 ft. above the bottom, and this kept out any wind or draught. In the hottest summer the house was perfectly cool.

Grass Camp.

When carrying out construction work in a tropical country, it may often be desirable to put up a temporary camp instead of living in a tent. It is unlikely that work would be continued during the rainy season and therefore the temporary camp need only last for the dry season. The easiest to erect and one which is exceedingly comfortable and cool during intense heat is one made entirely of grass. The natives of the district will be certain to be adepts in this kind of thing. No tools or materials are required beyond what the bush affords. A framework is erected as shown in Fig. 107, the pieces of which are tied together with withes. The grass for building must be long and straight, and is generally brought in by the women and put in place by the men, who fasten it to the framework, also with withes, as shown in Fig. 108. The dining-room is an open-air one consisting of an overhanging piece of the roof supported by sticks. The table and seat are also constructed of sticks fastened together in the same way as the framework.

Fig. 107. Building Grass Camp: Framework: Tropical Africa.

Fig. 108. Building Grass Camp: South-East Africa.

[To face p. 134.

Fig. 109. Grass Camp in Forest: South-East Africa.

Fig. 110. Forest Engineer's Camp: The Stable: Tropical Africa.

[To face p. 135.

A finished camp in which the writer lived for many months at a time is shown in Fig. 109. In this particular instance he had horses, and it might be mentioned here that it is very desirable to provide for these animals a shelter from the very heavy night dew in an unhealthy country. A stable was constructed in the same way as the camp and is shown in Fig. 110.

A camp of this kind gives shelter not only from heavy dew, but from light rains. If these should fall, they do not penetrate, and the camp is quickly dried up again by the heat of the sun.

A wide space should be cleared round even a temporary camp like this, and the grass burnt.

Rondavel.

For a more permanent residence in a tropical country, various kinds of buildings can be constructed. Very comfortable dwellings are the rondavels, which are so common in South Africa. The natives are particularly expert in building these, and while their ideas can be adopted, they can be modified to the more exacting requirements of the white man, if desired. They may be built of any reasonable size and are in the shape of a perfect circle, which the native is always able to accomplish. The foundation is levelled, upright posts put in here and there round the circle, and walls made of thin poles as straight as it is possible to get them. The roof is made of a framework in the same way and carried to a point. Spaces are left in the wall for door and window, and the walls are plastered thickly with mud. The roof is thatched with grass and a hole left in the peak for ventilation. This hole is covered by a tin cone to keep out rain, while leaving a sufficient air space. The construction is shown in Fig. 112. The floor is of earth beaten hard. This dwelling is the most comfortable imaginable in a hot country, being particularly cool even in very great heat, while is it warm in the cold nights. In malarious country a series of rondavels can be made for offices, living rooms, bedrooms and so on, connected with each other by a gangway covered with wire gauze, with which the windows are also covered. Dwellings of this kind are quite suitable for permanent use.

There is no intention in this work to attempt minute instruction in carpentry and joinery or to give elaborate designs for housebuilding. Where conventional masonry or brick houses are to be built, they furnish work for skilled artisans and these must be obtained, and the work of the Forest Officer should be confined to their general supervision. Throughout, the writer's aim has been to show what can be done in all kinds of construction with unskilled labour and with the least possible outside material.

Bungalows.

In a tropical country, much care should be exercised in the selection of a site for a dwelling place. It should be near a good water supply; but should be well away from any swamp or marshy ground. It should never be built in a hollow, but should be on raised ground so that it is kept dry. Local climatic conditions should be considered, and the house should not face the direction from which severe storms usually come. In some parts of the tropics, cool sea breezes come from the same direction practically every afternoon, and these should be taken into account. Inland, the afternoon sun is usually intensely hot, and provision should be made for shelter from this. Particularly, a site should not be chosen where a bare hillside rises behind the house, as this draws the heat of the afternoon sun and makes and keeps the atmosphere most oppressive until far into the night. No house should be built anywhere near a native village.

Piles.

The site is first levelled and the plan of the building marked by pegs, taking care that the corners are right angles. If the building is to be a light wooden one, it may rest on wooden piles driven into the ground or on concrete pillars. If the former, the underground part of each pile should be treated with Solignum before driving. In addition to treating it with two coats of the preparation,

Fig. 111. The Forest Engineer's Dining-Room : Tropical Africa

Fig. 112. Forest Headquarters, Mud Rondavels : South-East Africa.

[To face p. 136.

FIG. 113. BUILDING ON PILES: SUMATRA.
[By courtesy of Messrs. Major & Co., Ltd.]

[To face p. 137.

holes should be bored diagonally from the surface down wards about 1 in. in diameter and a few inches deep, and filled with Solignum. Each hole is then plugged with a tight fitting wooden stopper. Concrete pillars from 9 in. to 1 ft. square and as high as desired may take the place of wooden piles. Houses thus raised are drier than if built on the ground and are less liable to decay in a damp climate, as there is a constant free circulation of air underneath. Reptiles and other pests are less likely to invade the interior. Intervals of about 8 ft. should separate the piles or pillars. Stout beams are rested on these and the frame of the house built up with the beams as a foundation. Fig. 113 shows a building on piles.

Foundation.

If the house is to be on the ground, trenches are dug after the plan has been pegged out. For a one-storied building such as would be commonly required, if the soil is of average firmness the trench will be about 2 ft. deep and 18 in. wider than the wall is to be. The foundation is then laid, and it should consist of concrete, as this binds together throughout into one solid mass and so carries the weight of the superstructure equally all over it. The concrete should be composed of one part of cement, two parts of sand, and four parts of gravel or stone or brick broken small. Broken stone or brick with rough edges is to be preferred to smooth gravel. The cement, sand and stone or brick are all thoroughly mixed dry in batches and then again with water. (Salt water is not good.) The concrete is laid between shutters, that is, planks set perpendicularly to hold the mixture in place. A few inches of concrete are laid at a time and well rammed down, while another batch is being mixed and made ready to put in place. In dry weather, the concrete should be protected against too rapid drying, and for the first few days should be kept damp by means of wet sacks laid on it, or slightly watered daily. Concrete should be laid as continuously as possible, and if the surface has been allowed to harden, it should be chipped and swept clean and thoroughly wetted before another layer is put on it.

A concrete foundation should be 9 in. thick. Above that the foundation wall may be continued in brick or stone with lime. After the concrete is set, the erection of the walls is begun. If these are to be of masonry or brick, the concrete foundation need not be carried up to the surface of the ground, but may stop a few inches below it.

Wood Preserving.

In any permanent construction, whatever the climate, it is always advisable to treat with some kind of preservative all timber which has to be sunk into the ground or be otherwise inaccessible. In a tropical country, however, where there are so many insect pests, the protection of timber is a matter not of advisability but of necessity, if the construction is to last any time.

In countries infested with white ants it is, in the writer's opinion, a hopeless waste of money to carry out any construction with untreated wood. Paint, tar, etc., he has found useless, in fact in some cases they tend to hasten internal decay by closing the pores of the wood. He remembers one case, where on taking down a bungalow in West Africa for re-erection, the heavy looking ornamental wooden pillars of the veranda were found to consist of nothing but a shell of paint. They had been carefully and methodically given a heavy coat of paint twice a year to preserve the wood, but the latter had been eaten entirely away by white ants, leaving only the paint. Fortunately the pillars had not been designed to carry any weight.

There are various makes of wood preservatives, but to preserve wood against white ants and other tropical pests, none appears so effective, economical and convenient as the well-known Solignum. Its value in these respects has been abundantly proved after the most severe tests, and as it is not usually possible for the Forest Officer to construct buildings with a view to experiments, he will probably prefer a tried agent. Solignum in various colours can be used for decorative purposes as well, and no doubt this will be appreciated by those building their own permanent homes, but the side which appeals to the writer is the utilitarian one, the preservation of woodwork. It is usually applied cold with an ordinary flat painter's brush, metal bound for preference, and no skilled labour is necessary. When convenient, it is an advantage to heat it before using (about 160 Fahr. is sufficient), as this ensures better penetration of the wood, and when large quantities of timber of suitable size are to be treated before fixing, much time and labour can be saved by dipping the timber in an open trough or tank of Solignum, as shown in Fig. 115. A few minutes' immersion is quite sufficient.

Sawn ends should be thoroughly well dabbed with the brush, so that the whole sawn surface is saturated. If two brush coats are given, several weeks should be allowed to intervene between the two. All timber should be treated before it is put in place, and the Solignum applied direct to the wood itself, not over size, paint or other preparation, as this only nullifies its efficiency. One gallon will cover 300 or 400 square ft., more if the wood is planed.

Solignum is antiseptic and non-poisonous, and does not appear to increase the inflammability of wood. It is said to preserve stone and brickwork, but of this the writer has no personal experience.

Creosoting.

Creosoting for suitable timber may also be employed, but if this is done it should be under pressure, and for this special plant is necessary. Briefly, the process consists of forcing compressed air at a pressure of 80 to 100 pounds per square inch into the pores of the wood (previously air-seasoned or steamed in a retort), and, at a higher pressure, creosote oil, without relieving the air pressure.

Construction.

If the walls of the building are to be of wood or of corrugated iron on a wooden framework, the concrete foundations must be carried above the ground. If the floors are to be of wood, holes must be left in the concrete foundation, well above the ground but below the level of the floor, to allow ventilation. These holes are covered with gratings to keep out rats, mice, etc.

Along the top of the foundation walls are laid beams, the wall plates. The upright posts of the framework are tenoned and fitted into mortises in the wall plates and are tied together with horizontal scantlings by tenon and mortise. The frames of the windows and doors are fixed in like manner. The tops of the upright posts are tenoned into

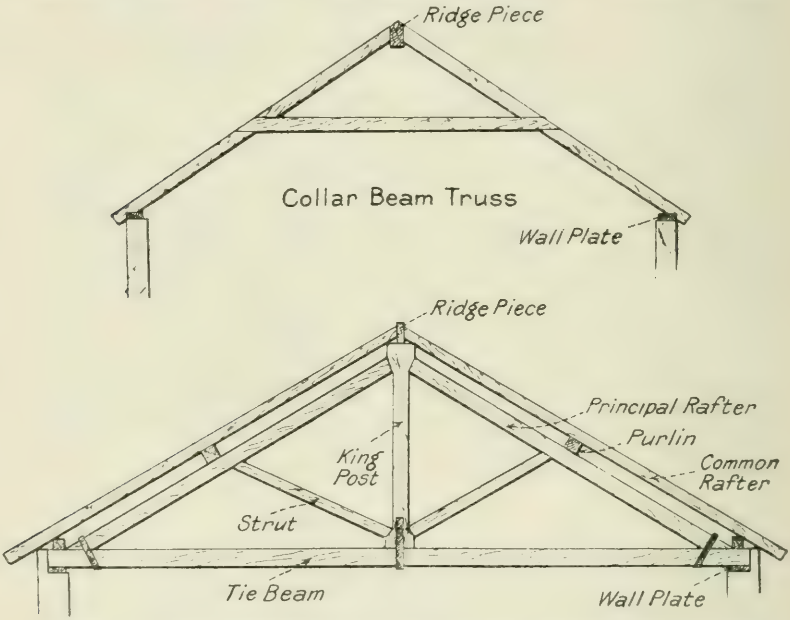

FIG. 114. COLLAR BEAM AND KING POST TRUSSES. SCALE $\frac{1}{8}$ inch = 1 foot.

mortises in the upper wall plates, beams similar to the lower ones, and the framework of the walls is complete.

Roofs.

The simplest roof is the ordinary gable one, rising from the walls at the sides to a peak in the middle sufficiently high to give the requisite pitch or slope to the roof. If the span from wall to wall is about 15 ft. or over, the roof should be carried on king post trusses. (See Fig. 114.) These trusses are spaced every 10 ft. or so from end wall

Fig. 115. Dipping Sleepers in "Solignum" Tank.
[*By courtesy of Messrs. Major & Co., Ltd.*]

Fig. 116. Mosquito-Proof Bungalow: South-East Africa.

[*To face p.* 141.

to end wall, and are tied together with the ridge piece and purlin, as well as being let into the wall plate. The purlins are notched where they cross the upper rafters. The common rafters are nailed to the ridge posts, to the purlins and to the wall pieces nailed along the tops of the tie beams.

The roof, of roofing boards, is now nailed to the common rafters, which are spaced 12 in. apart, and the covering—corrugated iron, tarred roofing paper, asbestos sheeting, or whatever it may be—fastened by means of screws or nails.

Corrugated Iron.

If the walls are of corrugated iron sheets, these are screwed to the framework, giving a sufficient lap at both sides and ends. Both in the walls and on the roof, the lowest course of the covering must always be laid first with the next piece overlapping. Matchboarding may be nailed to the rafters on the underside to form a ceiling, or a horizontal ceiling of canvas or other material may be preferred.

Weather Board.

Instead of using corrugated iron, the walls may be weatherboarded of lumber sawn in the woods. These are boards 1 in. thick and of even widths, and are nailed horizontally to the framework outside, beginning at the bottom. Each board overlaps the one below it at least 1 in., and is firmly nailed. When painted, it makes an excellent weather-proof wall. Corrugated iron should also be painted, as its appearance and lasting qualities are thereby much improved.

Whether the walls are weatherboarded or of corrugated iron, there should be an inner wall of matchboard nailed—perpendicular for better appearance—to the framework inside, and the space between the inner and the outer skins filled with sawdust or dry moss. Either of these is an excellent non-conductor of heat or cold, and will help to keep an even temperature.

If the floor is to be of wood, joists are laid from back to front at intervals of 12 in. on the concrete foundations, and the floor boards nailed to these. The joists should be of timber 9 in. wide by 3 in. thick, and are laid on edge, and supported underneath about every 6 ft. The partitions dividing the building into the various apartments are now boarded up, and doors and windows fitted in place.

Stoves.

In a house of this kind, fires are not likely to be wanted except in the kitchen. The best type of stove for cooking purposes is the "Columbia" stove to burn wood. The stove pipe can be carried up through the roof and, if the roof is of corrugated iron, all that is needed is to cut a hole in it. If of inflammable material, a large square should be cut out and a piece of sheet iron nailed over it, with a hole for the stove pipe in the middle. The floor of the kitchen premises and of the bathroom should be of concrete.

Mosquitoes.

In a malarious country, a veranda should be constructed along the front of the house, and the roof extended so as to cover it. The front and ends of the veranda should be enclosed with wire gauze and the outer doors of the house should be double—one ordinary door opening inwards and one of wire gauze opening outwards. The latter should have a spring to make it shut automatically. The windows should be covered outside with wire gauze in a detachable frame (Fig 116).

If the floor of the veranda is covered with cocoanut matting, no snakes will cross it.

Pisé de Terre.

Instead of corrugated iron or sawn lumber, the walls may be of pisé de terre, that is, rammed earth, a form of building as old as the ancient Romans. The material for this should be easily obtainable by the Forest Officer. A concrete foundation should be constructed as before, but continued to a height of about 9 in. above the ground level. Pisé de terre walls should be 18 in. thick, and a damp course of slate or bitumen should be laid on the

FIG. 117. BRICK AND PLASTER BUNGALOW: NIGERIA.
[By courtesy of Messrs. Major & Co., Ltd.]

[To face p. 142.

foundation. Earth that is clayey or sandy is unsuitable, but except for this any ordinary earth can be used as it is dug. Stones the size of a walnut or less are left in, as they help to bind, but any larger are kept out. Organic substances in the earth are bad, as they shrink in drying and tend to crack the wall. Top or vegetable soils are therefore unsuitable. Soil should not be used wet ; as long as it will consolidate under the rammer without pulverising it is damp enough. If it is wet, the walls will crack in drying. Shutters of 2-in. planking are set on the concrete foundation to form the walls, and are kept the requisite distance apart to give the thickness by bolts. Earth is now filled in between the front and back shutter to a depth of 4 in. and rammed hard. The rammer should be of iron with a flat face, and should weigh about 7 lbs. The earth is rammed till the rammer brings out a clear ringing sound. Another layer is then filled in and rammed and the walls are gradually built up, the shutters being lifted higher and higher and rested on the top of the finished parts.

The shutters should be about 10 ft. long, and the walls built up in sections of this length 2 ft deep. One section length is bonded to the next by shaving down the ends to an angle of 45°, thus forming a splice. Operations should if possible be continuous, but the finished portions of the wall should be covered over with sacking at night to keep the wall damp and make it unite properly with the next section. Operations cannot be continued in wet weather, and the walls must be covered over to keep rain off until the whole is finished.

The bottom of the walls outside should be tarred to a height of 2 ft., and the remainder rendered externally by being washed over with a mixture of sand and ground lime in equal quantities. The walls inside can be plastered and distempered.

Wall plates are set along the top of the pisé walls, and the roof constructed as before. The outer covering of the roof may be thatch, which gives a very fine appearance to a house of this material.

Brick.

A pisé building can be constructed entirely with unskilled labour, but the Forest Officer may be able to obtain materials for making bricks and lime ready to hand, and if this is so, it may be desired that the walls should be of brickwork. This would be set on the concrete foundations, with a damp course of slates or bitumen above the ground level but under the floor level. The actual bricklaying requires at least some skill and experience, and labour for this must be available, if the building is to be constructed in a workmanlike manner. It is not proposed, therefore, to attempt instructions in actual bricklaying. It may be emphasised, however, that in laying bricks they must be bonded, that is, joints must not coincide. There are various kinds of bonding, the commonest being possibly the English bond. (See Fig. 118.) The brick laid longways is a stretcher; that laid over and across two stretchers is a header ; the cut down brick is the closer, which is used to finish a length when a full-sized brick would be too large. This is the style of building a solid brick wall, but for a dwelling such a wall is not particularly suitable, as it is apt to admit damp unless it is faced with cement outside. A more satisfactory wall is built with an outer and inner skin of one brick thick, with an air space between. The two skins are tied together by means of pieces of galvanized metal placed at intervals on the top of the courses, and built in by the next course being laid on them. These pieces of metal are short strips shaped like the letter " X," and are about a quarter of an inch thick. Each arm of the " X " is half an inch to an inch wide. This wall will effectually exclude wet and give a more even temperature in the house. The bricks are bonded as shown in (upper) Fig. 118. The walls must be kept plumb and square and perfectly level as they go up. The frames for windows and doors are nailed to wedges driven into cracks between the bricks. When the walls have reached the full height, wall plates are fixed along the top and the roof constructed as before.

Brickmaking.

Good bricks are easily made if suitable earth is available. This is clay mixed with sand, ashes or chalk, and while it shows certain ingredients when analysed, the Forest Officer is probably without appliances for analysing, and must adopt some rough and ready method of ascertaining the suitability of the earth at his disposal. If the clay and sand are mixed with water and kneaded till of the necessary consistency for moulding, a ball of the mixture may be squeezed in the hand. If it does not stick to the fingers, it should make

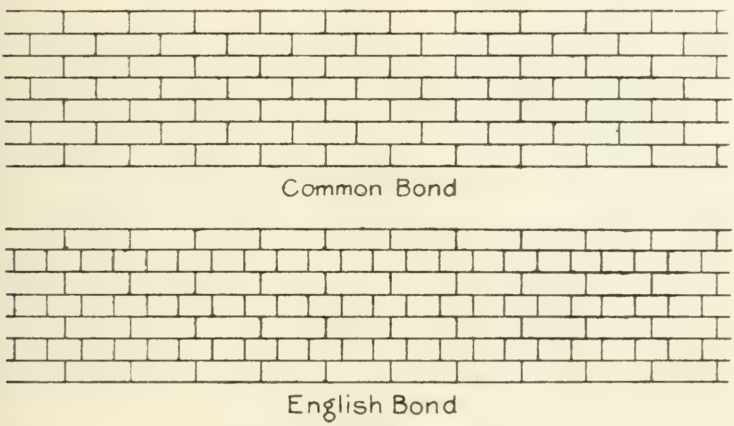

FIG. 118. BRICK BONDING.

satisfactory bricks. If it sticks, there is not enough sand and more must be added. When a satisfactory mixture would appear to have been obtained, some experimental bricks should be made and sun-dried. If they do not crack in drying, they should be good. Those experimental bricks should be burnt, and if they stand well and ring clear when knocked one against the other, brickmaking in quantity may now be undertaken. In preparing the earth, the upper covering of the soil is first removed and put aside. The earth for brickmaking is then dug and all stones, roots and other impurities removed. It should be dug some months before use and left exposed to the weather, as this breaks it down and increases its plasticity. When it is ready, it is mixed with water and worked for several days by treading or with spades, till the whole mass is of the consistency of putty. Bricks vary in size, but the stock size is $8\frac{3}{4}$ in. by $4\frac{1}{4}$ in. by $2\frac{3}{4}$ in., and should weigh about 5 lb. A brick is made in a wooden mould, which has no top or bottom and is one-twelfth larger than the finished brick to allow for shrinkage in drying. The mould is placed on a flat board and sanded inside to prevent sticking. The prepared clay is then thrown forcibly in, and pressed firmly down. The top is trimmed off with a wire. The mould is then slipped off and the brick, when firm, is taken to a level drying floor to be dried in the sun. The result will be a perfectly flat brick. If the mould is laid on a board which has a raised piece less than the size of the brick nailed to it, the pressure of the clay in the mould will result in a brick with an indentation the size of the raised part. A similar indentation can be made by pressure on the upper side of the brick. These indentations are known as frogs, and in building they are filled with the mortar and make a stronger joint.

The drying floor must be level and well drained. To dry the bricks, they are stacked on edge with plenty of air space between, one layer being placed longways of the floor, the next layer across this one at right angles and so on. They are sufficiently dried when the pressure of the finger on the brick leaves no mark. Sun-dried bricks with mud mortar can be used in building, and plastered on the outside with mud, but they will not stand like burnt bricks.

Bricks can be burnt in a clamp with alternate layers of fuel and bricks, but as the fuel burns away, the layers of bricks may sag unevenly and many of them become distorted or broken. The simplest kind of kiln is no more difficult to construct than a clamp, and the results are much more satisfactory.

The bricks to be burnt are built up into a rectangular stack 7 ft. or 8 ft. high and much longer than wide. They are stacked round several flues, which are kept filled with fuel during the burning process. The ground for the kiln must be accurately levelled.

Brick Kiln.

A wall of three bricks' width, close together the whole length of the kiln, is carried up not less than five or six courses and bonded, as shown in Fig. 119. Three feet from it a similar wall is laid exactly parallel. The space between will be the flue, and as many flues are made as the quantity of bricks requires. When the walls reach the desired height, the courses of bricks begin to overlap till they form arches, as shown in Fig. 119. Along the top of the arches is laid one course of bricks close together, to form a roof, and on the roof are now stacked the remaining bricks to be burnt.

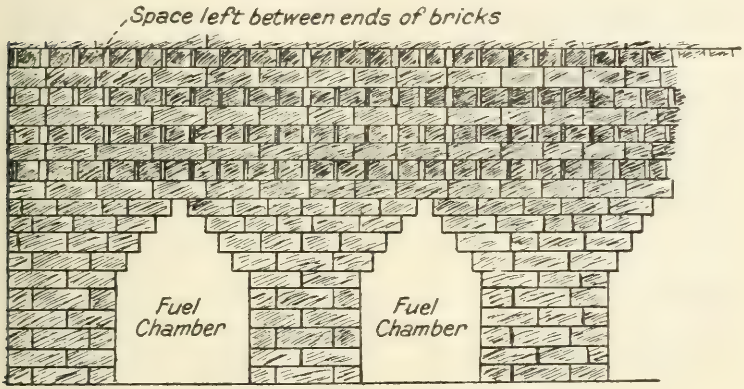

FIG. 119. BRICK KILN. SCALE ⅜ inch = 1 foot.

They are laid in alternate layers, each one at right angles to the layer underneath, and touching at the ends but leaving a space between the sides as shown.

When the stack is complete, the sides are plastered over to keep the heat in. The flues are filled with a slow-burning fuel, such as charcoal, hardwood, dried cowdung, or whatever may be most easily procured, which is then fired. Burning bricks correctly requires the greatest care in regulating the heat. It must be gradually increased so that the bricks do not dry suddenly and crack. Regulating is done by covering up or opening the fire holes. The state of the bricks should be tested by taking a few from the top and trying them. If they are well burnt, the whole stack should be ready, and when this is the case all the fire holes are stopped up and the whole mass allowed to cool very slowly, or many bricks will crack. Burning may take from three days to one week.

Lime Burning.

If limestone deposits exist, lime can be manufactured locally. A layer of a slow-burning fuel is placed on the ground in the form of a circle to a depth of about 2 ft. A layer of equal depth of limestone, broken to about the size of a tennis ball, is then placed on the fuel, then alternate layers of fuel and broken limestone in a circle of narrowing diameter, till the top layer of fuel is reached and the clamp is in the form of a dome. An opening is left in the centre of each limestone layer, which leaves a flue running from bottom to top of the pile, which is filled with fuel.

The fuel at the bottom is lit, and burning is continued till the whole of the limestone is white hot, when it is gradually cooled. When water is added, the burnt limestone is reduced to a powdered lime, ready for use.

Water Supply.

If no running water supply is near at hand, it will be necessary to depend either on the rain that falls or on wells. Unless the roof is a thatch one, the water running off it should be caught and stored. Gutters, which may be of wood, are fixed on the top of the walls under the eaves and led to one or more downpipes, which connect with corrugated galvanised iron tanks. When running water from the roof is collected for domestic use, it should be arranged that the first rain after a dry spell is allowed to run to waste and not stored. The roof will be foul with bird droppings and other matters, and should be washed as indicated.

Wells.

If a well is to be the source of supply, it should be sunk on low-lying ground, but not right at the bottom of a valley or hollow, or it will collect drainage as well as water. It can be lined either with timber or with brick. If the former, the well should be square and the sides held up with horizontal beams. When the extreme bottom of the well is reached, four beams are placed on the bottom forming a square. Upright posts, 6 ft. long, are now spiked to the four corners, and four more horizontal beams rested on, and spiked to, the tops of these, and the walls are built up to above ground in this way. The lowest section is laid down when the water has begun to collect, and after it is laid the earth is dug away underneath the section to sink it, and the bottom kept clear of water as long as possible. When the section is sunk to the lowest attainable depth, boards are fastened perpendicularly to the outside of the framing, and the wall built from bottom to top. Earth is filled in behind the lining and well rammed down.

If the well is to be lined with brick or masonry, it is circular in shape. When water is reached, a wooden frame in the shape of a ring of the same circumference as the well is laid on the bottom, and a few courses of lining built on it. Excavation is continued as long as possible under the frame, which is gradually lowered with the section of brickwork on it. This must be done evenly.

The lining, either of timber or brick, should be continued several feet above the ground level to prevent surface water running into the well.

Should a house be within a reasonable distance of running water fit for domestic use, the water may be led directly to the house through piping, and if it can be brought from a higher level, no force is required to bring it. If, however, the point of supply in the stream should be at a lower level, the water can easily be raised by means of a ram, worked with a paraffin engine. The latter need only be at work while the water is actually being pumped, and when not in use for this purpose may be used for generating electric light or for any other purpose.

Hygiene.

Particularly in a hot country, and most of all in a malarious one, every attention should be paid to hygiene and sanitation. Everything that tends to one's comfort in such a country promotes and conserves health. The equipment of a house in such circumstances need not be very elaborate.

Simple but ample ventilation must be provided. Square openings should be cut in the gables of the end walls, and louvres fitted into the openings. These are wooden slats about 3 in. wide nailed across the openings about 2 in. apart, and slanting downward and outward, so that each slat overlaps the one underneath, and still leaves a space. This method allows the free entry of air, but excludes rain. Insects are excluded by tacking a piece of wire gauze across the whole square inside.

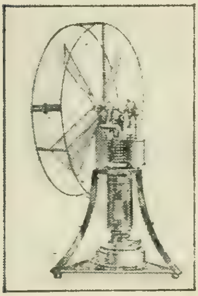

FIG. 120.
PORTABLE FAN.
[By courtesy of Model Engineering Co., Ltd.]

Fans.

Should power be available and the dwelling wired for electric light, fans should be installed in all the rooms. They add immensely to comfort and health, and to a great extent keep mosquitoes and other insect pests away, and often, in hot, sultry nights sleep is impossible without them. If no power is available, portable fans can be procured. A particularly light and effective portable fan is illustrated in Fig. 120. It runs for many hours without attention on a very small consumption of kerosene.

Heating.

If heating is wanted in the house, the simplest way of carrying this out is to have stoves which burn wood and from which stove pipes go directly through the wall or roof, the pipes being packed round with asbestos sheeting at the points of contact with these. If fireplaces are required, they must be built of brick or stone, with chimneys of the same. If the house is brick or stone the chimney is built in the wall. If a wooden house, the chimney must be built specially.

A chimney flue should be about 14 in. by 9 in. It should not widen out again after being narrowed above the fireplace, or afford any place for soot to lodge in pockets, and care should be taken not to leave any of the joints between the bricks open, or smoking will result. The flue must not go straight up, but should be given a bend. The fireplace must have a hearthstone, which can be of concrete.

Sanitation.

Even if mosquito proof doors are kept shut, flies will get in somehow, and are a danger to health as well as an annoyance. The writer found it added greatly to his comfort to keep an ordinary fly swotter made of a piece of wire gauze on a stick in every room in his bungalow, and to insist on its prompt use.

All empty tins ought to be buried—never thrown out. If they are thrown out they collect either rain or dew, and form an accommodating breeding place for the mosquito in close proximity to the house.

If there is no drainage system it is impossible not to empty out slop water on the ground, but it should be carried some distance from the house. The writer had a pit dug about 6 ft. deep and filled up nearly to the top with loose, irregularly rounded stones. The rest was then filled in with soil, and the native servants carried and emptied all slop water there, and the result was satisfactory. All fluid percolated away, and in several years' hot weather there never was the slightest nuisance. The pit must be dug in such a situation that there can be no seepage from it to any water supply.

Rainwater should not be allowed to drip from the eaves to the ground round the house. If it cannot be caught and stored, it should be drained away, or it may sap the foundation of the house, and in any case will keep the house damp. A trench should be dug all round the house and loose stones filled in and covered with earth to the ground level. The trench should slope to a point from which another trench of the same kind leads to the pit already described, and should join it underground. The whole surroundings of a house in a hot country, and particularly if malarious country, ought to be well drained, and it ought not to be possible for even a rain-water puddle to collect.

All kitchen refuse and garbage of any kind must be burnt and on no account thrown out. Nothing should be left undone to prevent both the breeding and the feeding of flies. All dry food of every kind, such as groceries, ought to be kept in tins with tight-fitting lids, while all perishable food, such as meat, fish or milk, ought to be kept in a shady place inside a wire gauze safe.

Sanitation is a troublesome, but most important, matter in the isolated dwelling in which the forest worker is likely to find himself. There will usually be no sewerage system, and he will probably have to depend on an earth closet. A small wooden outhouse should be erected at some little distance from and out of sight of the dwelling. The floor should be of concrete and the openings for ventilation covered with wire gauze. It should be made absolutely fly and mosquito proof, and should be well lit by a window of obscured glass. If a sufficient supply of dry earth and a disinfectant powder is kept and used, and the receptacle emptied and its contents buried daily, there need be no nuisance at any time. A convenience of a similar nature is necessary for any servants or labourers, either in camp or in houses.

A house may have indoor conveniences and an indoor water supply for flushing. In this case the sewage and slops can be led away from the house in earthenware pipes, which should if possible end in a septic tank, not in a cesspool. A septic tank is neither difficult nor costly to construct, and completely purifies the sewage by means of bacteria. The resulting clear water can be run into a stream without any harmful effect. If a septic tank is used, no disinfectant or antiseptic may on any account be allowed to come into contact with it, as these would kill the bacteria which do the purifying. A septic tank is unsuitable for a country where hard frosts prevail, as the outlet for the clear water is certain to become frozen, when the tank would cease to work.

A most ingenious and satisfactory indoor system is to be had in the Elsan Chemical Closet. This is installed where no sewerage system exists, and is entirely suitable for dwellings in the conditions under which the Forest Officer lives. The comfort of having such an appliance indoors at all times, but particularly in sickness, cannot be exaggerated.

The closet in appearance is the same as we are accustomed to in well-fitted houses in this country. A tank is fitted underneath it, out of sight, in which is placed a small quantity of a special chemical dissolved in water. This chemical liquefies all sewage, paper, etc., and completely sterilises the fluid, killing all germs. When the tank is full the contents are drained away into a soakway, which can be situated anywhere convenient. There is no odour at any time, and no attraction for flies. The first cost of the appliance is low, and the cost of maintaining it is negligible. A portable model is also obtainable which is completely self-contained, and can be easily installed inside the building.

This closet has been installed and recommended by H.M Government sanitary advisers, under all conditions and in all countries.

CHAPTER XII

ROADS AND BRIDGES

Aligning roads—Making drift or ford—Unmetalled road—Metalled road—Hill road—Drainage—Crib bridge—Crib and pile bridge—Strut bridge—Truss bridge—Suspension bridge.

BEFORE selecting a line for a road, it is necessary to go carefully over the ground, noting the general configuration and any movable or immovable obstacles with the view of settling the best line and easiest gradient. The latter should average about 1 in 50 for a permanent road, although it may be steeper in places for a short distance.

Aligning.

In going over a hill range, the road should if possible be carried over any saddle at the lowest point.

The line having been settled, it is marked out by a series of pegs driven into the ground to the proper level. Larger pegs should also be driven in on the same line to make the general run of the road easily picked up.

The most difficult parts of a road should be set out first and the simpler portions joined up with these.

Construction.

Construction should not be begun until the whole road or a quite definite section of it has been set out, in case some unforeseen difficulty causes the whole line to be radically altered.

In flat country a track should be cut through the bush wide enough to cover both the width of the road and a drain at each side. All stumps should be removed entirely as, in a hot, wet country particularly, they quickly rot and leave awkward holes in the road. If the road is not to be metalled, all that is now necessary is to grade it roughly, flatten down any inequalities and remove any rocks or

FIG. 121. MAKING DRIFT OVER RIVER: SOUTH-EAST AFRICA.

[To face p. 155.

other obstacles, and dig the drainage ditch at each side. No fixed rule can be laid down for the width and depth of the ditches, as these will depend on the rainfall and the quantity of water to be carried off, but as a rule they should be about 3 ft. in depth and the same in width. The earth from them can be spread on the road to give it a slight fall from the centre to the sides. This road will remain perfectly good during a dry season and also during the lighter rains, but will not stand any heavy traffic during the rainy season.

Fords.

If any rivers are crossed by such a road, it is not probable that it will be worth the expense of constructing bridges to carry it. It can be taken to a suitable place at the river where the water is naturally shallow and a drift or ford made there. If the bank is steep, it must be cut away at each side the width of the road to give an easy grade for vehicles from the natural level of the road down to the river bed. Stones of similar size should be placed in the bed of the river all the way across the drift and roughly levelled, so as to create a known bottom and also to give good footing for animals, and make the crossing safe even when the river may be in flood and the bottom cannot be seen. Where the road enters the river, it will probably be cut away after any flood to some extent and will require frequent repair (Fig. 121).

If the road is to be a permanent one for use in both rainy and dry seasons, it should be metalled. It requires first of all to be properly aligned, graded and ditched. Stones are broken to a size which will just go through a 6-in. mesh and a layer of these is first placed on the bed. On this, to a depth of 6 in., are spread stones broken down to pass through a 2-in. mesh. These smaller stones are repeatedly rolled by heavy rollers or beaten down firmly with beaters and covered with a thin layer of gravel which helps to bind the surface. Such a road should be slightly convex, sloping from the centre of the road to the sides.

Hill Roads.

In carrying a road along the steep side of a hill, the lower side may be built up with cribwork, with the bottom of the crib securely let into the ground. The crib should be filled with rocks and the road made on the top of this. For greater safety on a sloping hillside, instead of cribwork, piles may be driven into the lower side and the road filled in. The method of constructing cribwork has already been described.

Or ground on the upper side may be cut away and the earth used to bank up the lower side. If the cutting leaves a steep wall of earth on the inner side, a retaining wall of brick, stone, or concrete should be built to hold it up, the retaining wall sloping slightly inwards. Drainage holes must be left in the retaining wall at intervals to prevent water lodging behind the wall and so in time bulging it with its weight or bringing it down altogether.

If the rains are heavy and the road liable to be washed away, a similar retaining wall should be built on the lower side to hold the made road.

Drains.

On a steep hill road cut out of the side of the hill, it is usually better to slope the road into the hillside and make the drainage on that side. A deep drain should be cut to convey the surface water from the road, and the water allowed to escape from it at intervals through drainage pipes going under the road itself. Each drainage pipe under the road should project into the open in the form of a spout, and stones should be laid under it, or the rush of water where it falls will gradually carry off the surface of the soil and may weaken the road at that point.

Where open cross drains are made on the surface of a road to carry, either into the main drain or over the hill, water which would otherwise denude the surface of the road in a heavy downpour, these cross drains must be wide and shallow and lined with stones. If deep and narrow, they severely jolt any motor cars or other vehicles passing over them. If a small stream crosses a road, it should be carried across in the same way in a wide shallow drain.

In countries where there are definite wet and dry seasons, road repairing should be undertaken at the end of the rains so that it will not be interfered with by the weather, and the newly laid down surface will have a chance to settle and bind without being washed away or cut into. The drains must be kept clear.

In determining the line of a long road through new country regard should be had not only to the immediate purpose for which it is required, but to its future possibilities of serving a district.

Bridges.

Bridges may be required to carry a road over streams or gulleys, and as with housing, so with bridges. It is not proposed to describe in detail the construction of an important steel or concrete or masonry or brick bridge. If such has to be built in any forest country, it is probable that it will be constructed by a Department of the Government whose special business it is. The bridge required of the Forest Engineer is likely to be a more primitive structure.

Crib Bridge.

The simplest to construct is the crib bridge or, for longer spans, the crib and pile bridge.

If the road is to be carried across a stream at a good height above the ordinary water level so as to allow flood water to pass, it can be built of cribwork alone or cribwork with piles.

The bank on each side must be first cut down deep enough to get a perfectly solid foundation for the bottom of the crib. When this has been reached, four logs, 12 ft. long and 18 in. in diameter, are placed at right angles to the flow of the water, one end of each log being at the edge, and the other being let into the bank a couple of feet. The logs should be spaced 18 in. apart. Across these at right angles are laid three or more logs of the same length and diameter. The first one is 6 in. from the front of the crib and the others are spaced about 2 ft. apart. The logs of the crib are notched and spiked as usual where they cross. The crib is now built up in the same way till the desired height is reached. All the logs of this crib should be barked and should be treated with "Solignum," especially in tropical climates. The crib should be decked and filled with rocks to give it greater stability.

Although this bridge is designed to carry heavy logging traffic, if the span from one crib to the other is no more than 12 ft., no intermediate support need be erected. Logs of from 15 in. to 18 in. in diameter roughly squared can be laid across and spiked to the cribs at each end. These span logs should be 2 ft, to 3 ft. apart. They are now decked with 3-in. planking or hewed poles nailed crosswise half an inch apart, and the top of the cribs filled in to the road level with stones and earth.

If the span is more than 12 ft., the road must be supported between the banks. The support may be a crib built either in the dry bed of the stream or put together on the bank and floated out and sunk in place. The supporting crib should be a three-cornered one with the apex pointing upstream. The two sides of the crib facing the banks should have poles spiked close together perpendicularly to the outside of the horizontal logs from the bottom to above high water mark, so as to throw off any logs, etc., which may come down in a flood. If the crib is left open or square to the current, floating logs in a flood may damage or move it. The crib must be decked and filled with rocks as usual.

Instead of a crib, a row of piles may be driven to bedrock or to good holding ground, and braced and capped, as described in Chapter VIII.

In no case should a span be greater than 12 ft. for heavy traffic.

If the bridge is to carry a forest railway, a series of logs are not stretched across, but two stringers, each 16 in. by 9 in., bolted together 2 in. apart, are laid across from crib to crib under each rail and spiked down. Sleepers are spiked to the stringers and the rails to the sleepers, as described in Chapter IX.

Lighter bridges for cart or motor car traffic can be simply built of timber and may have a greater span than the foregoing. They may be varied according to the local conditions and as suggested by the judgment of the Forest Engineer on the spot. But they may be roughly divided into two types, a bridge supported by struts and one supported by trusses, neither of which requires an intermediate support.

The supports on each bank may be built up of cribwork as before, or they may be of masonry, but into the building of these latter it is not intended to enter here.

The span may be of 40 ft. to 50 ft.

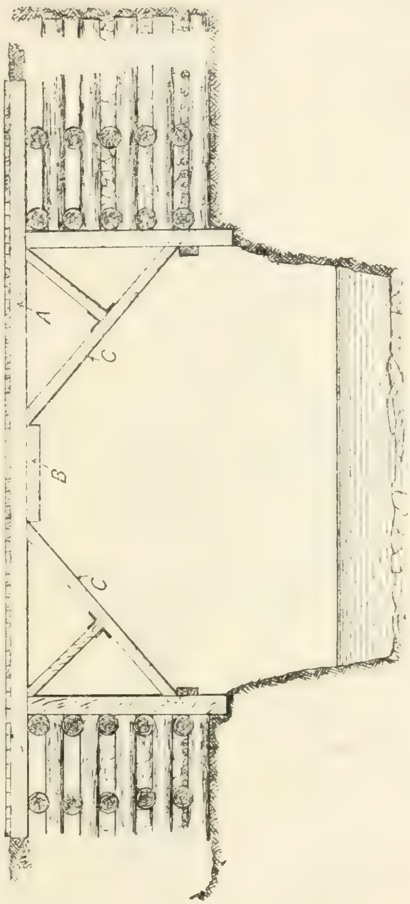

FIG. 122. STRUT BRIDGE WITH CRIB PIERS. SCALE $\frac{1}{16}$ inch = 1 foot.

Strut Bridge.

Three or more heavy square timbers are laid across from crib to crib at equal distances and spiked. (See A, Fig. 122.) To the under side of the middle of each timber is bolted a short piece, B, of nearly the same cross dimensions. Struts, CC, are now fixed as shown and spiked in place. One end rests against, and is spiked, to the short timber, B, and to the longitudinal beam, and the other end is spiked to an upright timber which is bolted perpendicularly to the face of the crib. A step is cut in the upright in which the lower end of the strut, C, rests. The struts should be at an angle of 45°. If beams long enough for the span cannot be obtained,

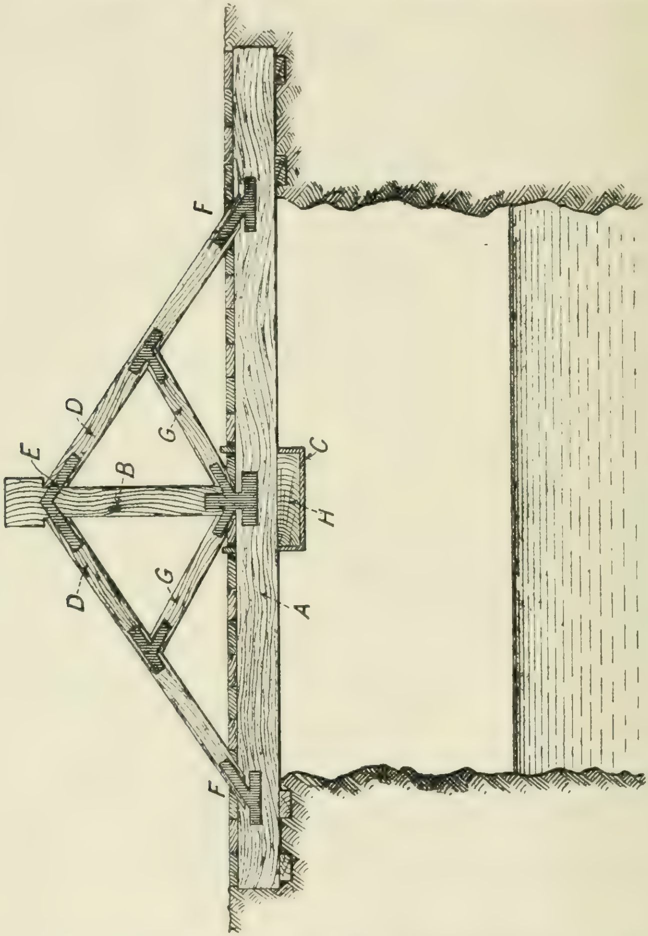

Fig. 123. Truss Bridge. Scale ⅛ inch = 1 foot.

they may be made up of two lengths and may rest on B, which should in this case be longer than shown in the drawing, to give sufficient support and to which they must be securely bolted.

Truss Bridge.

If it is impossible to have struts under the bridge, the latter may be supported by a truss, as in Fig. 123. In this case the timber, A, must reach from crib to crib. An upright timber, B, is set up perpendicularly in the middle of the beam to a height of nearly one-third of the length of the span. It is fastened to the beam by an iron plate, bolted to both timbers. This is the king post. From the top of this, timber struts, DD, are fastened by similar plates at E to the top of the upright, and at FF to the beam, into which they are slightly sunk and to which they are spiked or screwbolted. The braces, GG, are now placed in position as shown, and fastened at both ends by similar iron plates. In all these plate fastenings there should be a plate on each side of the timber, and screw bolts should pass right through the timber and both plates and should be screwed up tight. This is better than tenon and mortise in such a situation, as these weaken the timbers.

A cross timber, H, should be fastened to the under side of the middle of each outside longitudinal beam for the support of any inner beams. The fastenings are straps of ½ in. iron, and are shown clearly in the drawing.

Three-inch planking or hewed poles are nailed crosswise on the longitudinal beams, again leaving between them a space of half an inch or so for drainage purposes and also to allow swelling of the wood when wet without causing warping or buckling.

In all the bridges described, if for cart or motor traffic, it is advisable to nail lighter planks at each side of the roadway to carry the wheels of vehicles. When these planks wear away, they can be replaced before the main timbers of the bridge are affected by the traffic.

In selecting the site for a bridge of any of the foregoing types, care should be taken that it is not at a bend of the river, as the erosion is greatest at such a point and the supports may be undermined in time.

The only other type of bridge the Forest Engineer is likely to be called on to construct is a light wire suspension footbridge over a wide river or chasm where no intermediate support can be provided, and where the span is too great for either a truss or strut bridge. To build a bridge with such a span to carry heavy traffic would be outside his scope.

Suspension Bridge.

In building a simple suspension bridge, the site of the pillars on each side should first be determined and the distance from one pillar to the other measured. The sag of the carrying wire ropes should be about one-twelfth of the span from pillar to pillar. The height of the top of the pillars above the level of the road may now be calculated.

For the pillars, four logs 18 in. in diameter, are placed upright on the ground, into which they should be sunk to about a quarter of their total length. The distance between two pillars on each side should be between two and three times the width of the roadway to be carried. A tie-beam should be bolted across to connect each pair of pillars at the top. On the top of each post is fastened an iron saddle on which the carrying rope rests.

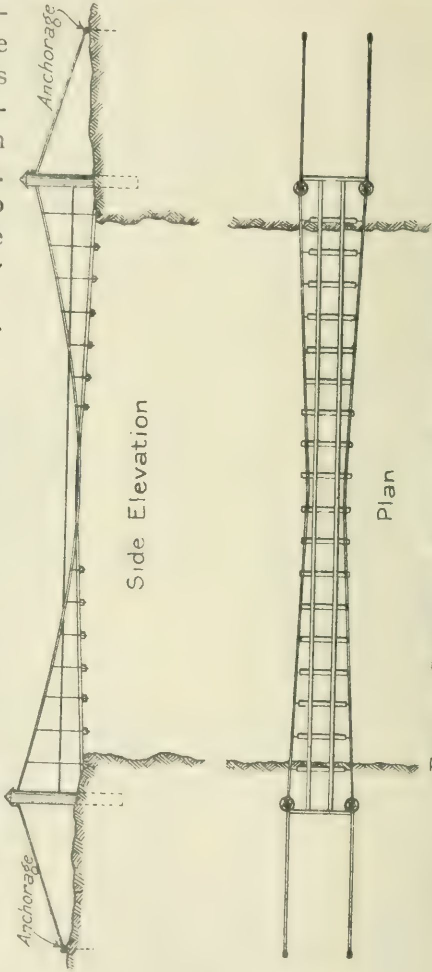

Fig. 124. Suspension Bridge. Scale $\frac{1}{32}$ inch = 1 foot.

The two carrying ropes are now passed over the four pillars and the four ends securely anchored in the ground well back from the pillars. A simple form of anchorage is formed by placing one 18 in. log across the roadway. This log is kept in place by two logs sunk at each end into the ground at an angle of about 60°, tight up against the horizontal log on the side next the bridge. Each pair of inclined logs should

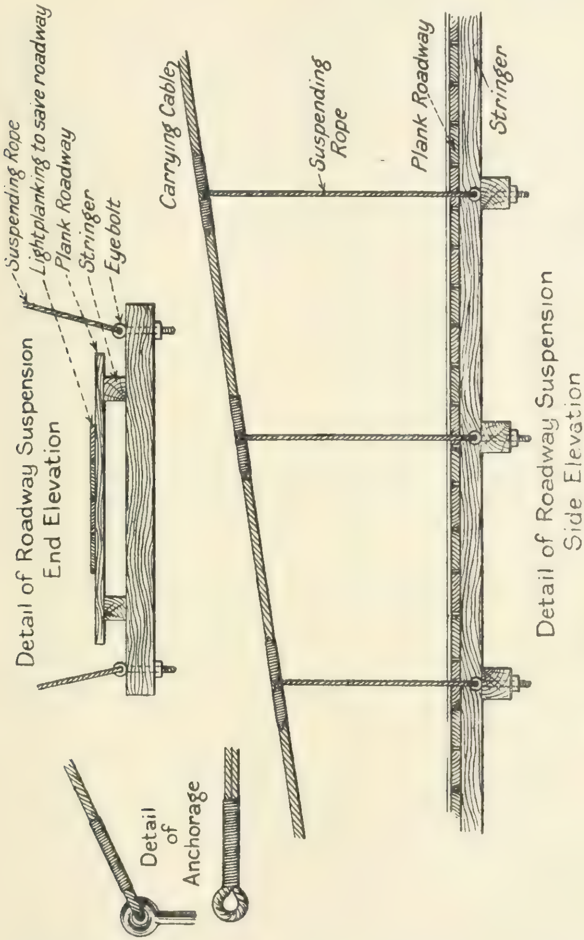

FIG. 125. SUSPENSION BRIDGE. SCALE $\frac{1}{4}$ inch = 1 foot.

be a few inches apart, and the end of the carrying rope is passed between these and through a hole bored in the horizontal log. The rope is then passed several times round this log, to which it is made fast.

If the anchorage can be on solid rock, holes may be drilled in it, and anchor bolts made of iron of 3 in. in diameter cemented or leaded in. The ends of the ropes will be passed through the eyes of the bolts, doubled back, and firmly bound with wire.

The roadway is hung from the two carrying ropes by means of smaller wire ropes. These are fastened at intervals of about 6 ft. to the carrying ropes by being passed between strands of the latter. The top end of each suspending wire rope is opened out into two sections, both of which are twisted round the main rope a number of times away from each other, and then bound firmly with wire.

Timber cross pieces, 6 in. square, to carry the road, are fastened to the suspenders by eyebolts. The screwed end of the eyebolt is passed through a hole bored in the end of the timber and screwed up. The lower end of the suspender is now passed through the eye of the bolt, doubled back, and bound with wire.

Instead of using eyebolts, the lower end of the suspender can be passed directly through the hole in the cross timber and the end bent out and twisted round the timber and bound with wire.

The suspenders should be so adjusted that the road is a little higher in the middle than at the ends.

Several of the cross timbers may be allowed to rest on the carrying ropes near the middle, if the sag should bring those ropes down to the level of the road, and should be bound to them with wire.

Two lines of stringers of 4 in. square timber are now nailed to the cross timbers 4 ft. apart all the way across the bridge, and a deck of 2 in. planking is nailed across the stringers, leaving about $\frac{1}{4}$ in. between each plank to allow for swelling.

A light wire fence should be carried across each side of the bridge on stanchions bolted into the deck timbers and supported where possible on the carrying cables and suspending wire ropes (Figs. 124 and 125).

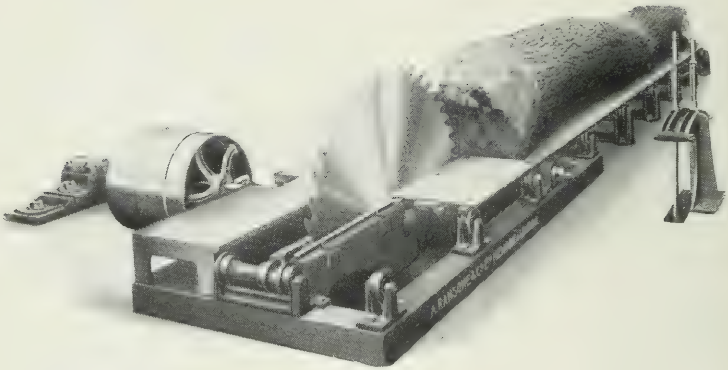

FIG. 126. RACK SAWBENCH.

[To face p. 165.

CHAPTER XIII

TIMBER CONVERSION AND SEASONING

Sawmill—Laying out and erecting portable and semi-portable sawmills—Handling logs and lumber—Sawing, stacking and seasoning lumber—Artificial drying and seasoning—Sawmill equipment.

THE planning and construction of a large permanent sawmill and woodworking factory hardly comes into the work of the average Forest Engineer. A portable or semi-portable sawmill, however, is necessary for the preparation of the lumber used in much of his construction work, and it is necessary to be able to operate one.

For small general work, if it is not desired to erect a complete mill, the " Forestry " saw bench illustrated in Fig. 5 is one of the handiest machines. It can be driven either by steam or by an oil engine. Probably the latter would be the more economical in use, if the oil fuel is fairly cheap and easily obtained. This bench has proved efficient and economical and can be packed for transport in very small space.

For a larger mill dealing with big timber, the rack bench with travelling table is a useful type. In a temperate climate the table may be of wood and the bench itself set on wooden blocks, as this all makes for lightness and handiness in frequent moving. In a tropical climate, however, especially with heavy rainy seasons and hot, dry spells, the wooden table is apt to warp and throw all the sawing out and indeed put the whole plant out of gear, causing hot bearings, buckled saws and all sorts of worries. In such circumstances if it is possible to have the bench of metal, so much the better. A suitable type of rack bench is illustrated in Fig. 126. This bench has a feed motion controlled by two hand levers conveniently placed, and speeded to give rates of feed instantaneously varying from a few feet up to 55 ft. per minute when sawing, and a return of the table of 150 ft. per minute.

In a mill doing a considerable amount of work, it is better to have two of these benches side by side, one for breaking down the logs and doing a certain amount of the subsequent sawing into planks, etc., and the other to take the remainder of the work for re-sawing.

As there is a very large amount of waste timber in a saw-mill which is of no other use than for firing, it is usually more economical to drive the mill by steam than by any other means. The driving power may be a traction engine moving about under its own power and driving the mill from the fly-wheel, but this is not usually so satisfactory as driving from a portable engine which has to be hauled from place to place. No building need be put up for a portable mill; in inclement weather a rough shelter can be made over it by erecting a frame of posts and rafters of poles, and covering the latter with corrugated iron, which can be used repeatedly, or with tarred roofing paper. If neither of these is available, the shelter can be roofed well enough with slabs or bark. The bark is stripped from the trees in sheets, soaked, and spread out flat on the ground with a weight on it for a few days to bring it into shape. The disadvantage of roofing paper or slabs is the risk of fire from sparks from the engine.

Portable Mill.

The use of a portable mill is to bring the saw as close to the timber to be sawn as possible to save hauling expenses. This should be clearly kept in view, as it is no use having a portable mill and then setting it up in a place which means an unnecessarily long haul. There are naturally some essential requirements in locating even a portable mill.

Water.

The first is an ample supply of water for the boiler. In hilly country there are sure to be streams above the mill site, and in this case the water can be brought down by a small flume made of rough boards. If water should be somewhat scanty and it is not desired to have it running all the time from some lake or storage pond above the mill, it can be siphoned down through a long piece of piping, into a cask standing beside the engine, and can be turned off when necessary. If the pipe is bent at the top end and the short piece put down into the pond, the water can be led through the long part to practically any distance, as long as the end at the engine is on a lower level than the end at the pond. To bring it into use, the end at the pond should be turned up and water poured in till the pipe is full, the tap at the lower end being closed. The top end can now be closed with the hand until the pipe is put in its place with the end beneath the water, when the hand can be removed. There will then be a constant supply of water for the engine without pumping, as long as there is water in the pond and there are no leaky joints in the pipe to admit air. To keep sand and mud out of the pipe its upper end should have a grating.

Storage.

The other essentials for a portable mill are sufficient storage room for the logs and sawn lumber and a good road out. The engine is placed at the head of the mill at one side, and the shafting and belting can be either overhead or underground. The main driving shaft goes from above the driving wheel of the engine across the mill at right angles. It can be carried in brackets resting on a frame of heavy beams. The first pulley is over the principal saw, the bench of which is erected true and square. The second saw, also a circular one but of smaller diameter than the first, is placed on a smaller bench exactly parallel with the first, but head to tail. Another pulley is on the driving shaft above this bench, and the driving belt must be crossed so that the saw will run in the opposite direction to the first. Between the two rack benches at the tail end of the first are short skids to pass logs or slabs from one bench to the other. From the tail of the second saw and in the same line, a number of free rollers are set in a frame, the other end of the frame ending at a crosscut saw bench. A countershaft is above this bench with a pulley which is driven from the main shaft, and a belt from the countershaft drives the crosscut saw. As the crosscut table is narrow, a set of skids is built up at the side away from the engine, both to rest the ends of long timber and to shoot out the timber which has been crosscut and is now finished with as far as this mill is concerned.

When the mill is set, three or four logs of about 12 in. in diameter are placed parallel with the first bench as the foundation for the log storage. The nearest log to the saw bench is about 3 ft. from the bench so as to allow the sawyer room to walk along when sawing a log or driving the table back. The other logs are spaced 6 or 8 ft. apart and the level slightly raised as they go away from the mill. On these logs skids of barked poles, 6 in. in diameter, are laid crosswise and spiked to the logs. The top side of the skids must be very slightly above the level of the saw table. To span the gap between the ends of the skids and the table, the sawyer keeps two or three short poles which he puts in place when rolling a log on to the table, and takes down out of his way when this is done. There may be a framework above to carry the shafting, and if a chain block and tackle is fixed up above the first saw table, it is a help in turning heavy logs.

If logs are dragged to the mill by animals, as is most probable, a slanting way must be made from the ground level up to a place which has been cleared and brought to the level of the skids, at the end of these farthest from the saw. This is the log storage.

Operating.

In operating, the logs are brought in and placed on the storage parallel with the saw bench. A good supply should always be on hand there, so that the mill may be kept fully employed. A log is rolled as wanted across the skids and placed on the first saw bench, where it is broken down. Part of it will be re-sawn on the main bench and what is not wanted for this is passed from the first bench across the skids to the second bench, where it is sawn up, and, as sawn, run along from the tail of the bench on the rollers to the crosscut, where it is dealt with and then passed out of the mill by the delivery skids. The timber has thus been on the move from the time the log entered the mill till the sawn lumber went out, without double handling and without coming back on its route. The waste slabs from the breaking down are thrown off the tail of the main saw and carried to the engine for fuel.

If logs are brought to the mill by a log carriage, a bank the height of the carriage must be made at the log storage, so that the logs can be rolled off easily. If the mill is on the edge of a lake and the logs go to it by water, a chute must be made coming out of the water up to the log storage at right angles to the skids leading to the saw bench, so as to make turning the log unnecessary.

Saws.

A useful size for the main saw is from 5 to 6 ft., for the second saw 3 to 4 ft., and for the crosscut 2 ft. in diameter. The waste at the crosscut goes to fire the boiler.

There is no edger in a mill of this kind as the plant has to be kept to the lowest possible effective amount. The edging is done by the two saws, and can be done quickly in the case of planks by putting a number of these on the top of each other and sawing them all at once. Saws in a portable mill will be sharpened by hand with special flat files.

Crew.

The time allowable for changing site is four days—one to dismantle, one to transport the plant, and two days to re-erect. The crew of such a mill consists of three or four men each with a horse to drag the logs to the mill, one fireman, two sawyers and two tailsmen, the latter to assist the sawyers at the tail of the saw, one sawyer for the crosscut, one labourer to carry out slabs, and three or four labourers to carry the lumber from the crosscut saw and stack it.

Semi-Portable Mill.

For a mill of a more permanent nature, some kind of buildings are necessary even in the forest or jungle, to give shelter to the men when working, to preserve the machinery, and to house a few men. Otherwise the requirements are much the same as for a portable mill. Additional plant can be installed, such as an edger and saw sharpener. The buildings can be quite rough erections either of logs built in the manner shown in previous chapters, or can be a rough framework walled and roofed with slabs.

In setting up a more permanent mill in the forest, it will still be found that the rack bench with a circular saw is the most suitable. Band saws and more elaborate plant are difficult to get in and to keep in good trim, and they hardly pay. The bench ought again to be of metal. No part of it is likely to be heavier or more unwieldy to handle than any part of the engine or boiler, and these latter are necessary unless direct water power is to be used or electricity generated by water power. If the engine and boiler can be transported, so can a mill bench. No fine work should be attempted in a forest sawmill, as the saws which are suitable for primary forest work are thick and it is not economical to convert timber into small stuff with them. The diameter of the saws will be suited to the size and amount of timber to be sawn, remembering that in dealing with hardwood particularly a saw should be bigger than is absolutely necessary, as a big saw, though requiring more power to drive, cuts more easily.

The bench may have a plain steel travelling table, but a more serviceable bench for all purposes is the steel girder frame log carriage with adjustable dogs to grip the log.

There should be as little wood about the bench as possible in a tropical climate, and where it is to be used for a foundation, etc., it should be seasoned and treated with "Solignum" to keep away white ants and other insects, as otherwise these will cause the early decay or collapse of the timbers, with consequent buckling or warping of the plant. The feed should be by wire rope and should allow quickening or slowing of speed during sawing. Speed, especially with partly unskilled labour, should not exceed 80 ft. per minute, varying according to the different kinds and sizes of timber, and the feed, to save extra countershafting, should be driven from the saw spindle. For sawing resinous timber

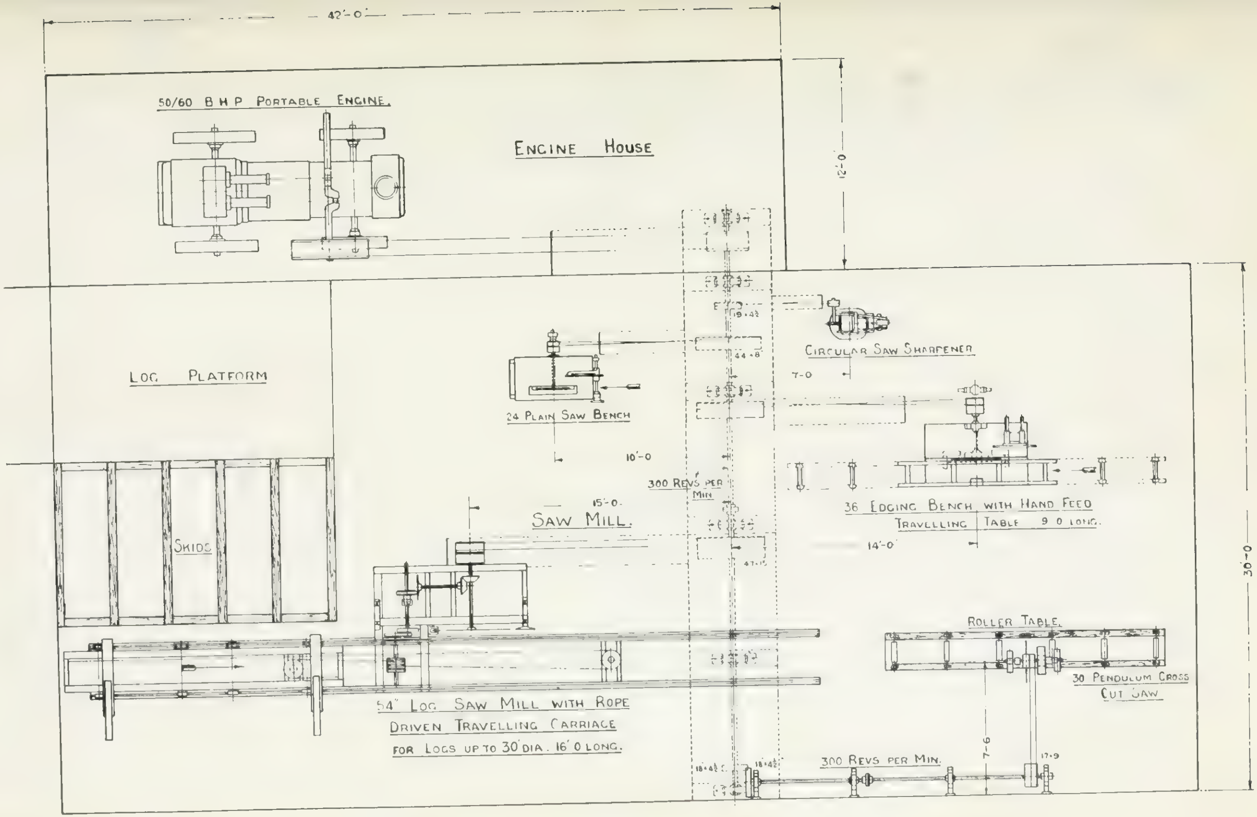

Fig. I.

Fig. 127. Plan of Jungle Sawmill.

[*By courtesy of A. Ransome & Co., Ltd.*]

[*To face p.* 170.

Fig. 128. Forest Mill in New Brunswick.
[*By courtesy of Canadian Government.*]

[*To face p.* 171.

solid saws are preferable, as the resin clogs inserted teeth. For other timbers inserted teeth are to be preferred, but whether they are used or not should depend on whether the labour is sufficiently skilled and intelligent to look after the plant properly. Saws with inserted teeth are not so apt to buckle and they do not require regulleting.

The foundations for the machinery are of rough hewn balks of timber mortised together, and as the shafting is carried underground, the walls of the pits may be of rough slabs. No stone, brick or concrete is necessary.

In laying out this mill the log storage and skids are put down as before, but as the carriage of this saw now being described is low, the skids must slope down to the level of the carriage and the log be rolled down, and fastened on the latter by the dogs.

The length of the timber carriage will be such as will suit the maximum length of the log to be sawn, but it is hardly likely to be necessary to saw anything over 16 ft. in length at the outside. Longer logs than these should be crosscut before coming to the mill. The carriage should be kept as short as possible to avoid difficulties in transporting; the additional sections for extension can be obtained and fitted if necessary.

Fig. 127, reproduced by kind permission of Messrs. A. Ransome & Co., of Newark, shows the lay-out of a mill which has been found particularly useful in jungle or forest conditions. The logs are dragged to the log platform and rolled to the carriage, where they are gripped by the adjustable dogs. When they are broken down to suitable sizes by this saw, the sawn pieces pass along the roller table to the pendulum crosscut saw, where they are crosscut to the required lengths. They are then passed over on skids or rollers to the 36 in. saw with hand sliding table, where they are further sawn to finished size. This secondary saw can be used as the crosscut and the pendulum saw dispensed with. The horizontal rollers shown at each end of this saw are a great convenience in handling.

A smaller crosscut saw should also be installed, as it can be usefully employed in converting small waste pieces and sawing up slabs for firewood, and so will save the time of the larger machines, which should be devoted to heavier work.

In the plan shown a simple saw sharpener has been installed, and if there is sufficient employment for it, this machine is particularly desirable in a country where highly skilled labour is not available. If circular saws are sharpened by hand, flat files must be used, not three-cornered files as for hand saws. Inserted teeth are sharpened by hand. Saw sharpening is a very important matter if the plant is to be kept in a state of efficiency and should be in the hands of a competent man.

For driving a mill such as illustrated, the portable engine should be of 50 B.H.P. or two engines of half this capacity.

Correct lubrication is important, and the makers of the plant are the best authorities to consult on this point. For belting a good balata belt with plate fasteners is generally suitable.

Such a sawmill as illustrated should put through in average conditions 60 cub. ft. of hardwood or 100 cub. ft. of softwood per hour, and should be operated with a crew of fifteen to twenty men, but all this will particularly depend on the nature of the timber, the climate, and the capability of the men.

A smaller mill can be run consisting of the same kind of log carriage and the 36 in. bench with the sliding table only, the latter doing the crosscut as well as part of the sawing into planks, scantlings, etc. It can be run with a 40 B.H.P. portable engine having a fly-wheel on each side, one belt from each fly-wheel driving each saw separately. No shafting would be necessary and the mill could be worked with a crew of twelve men. In the smaller mill, the output from the log carriage saw would be carried or wheeled round the back of the engine to the smaller saw.

Stacking and Air-Seasoning.

After being sawn at the mill, lumber should be carefully and systematically stacked to dry. It should be piled in lumber of equal lengths, as, if various lengths are piled in

FIG. 129. SAWMILL IN BRITISH COLUMBIA.
[By courtesy of Canadian Government.]

[To face p. 172.

Fig. 130. Progressive Artificial Seasoning Plant.
[By courtesy of Sturtevant Engineering Co., Ltd.]

[To face next plate.

FIG. 131. COMPARTMENT ARTIFICIAL SEASONING PLANT.

[By courtesy of Sturtevant Engineering Co., Ltd.]

[To face last plate.

Fig. 132. Compartment Artifical Seasoning Plant.
[By courtesy of Sturtevant Engineering Co., Ltd.]

[*To face p.* 173.

one stack, the longer boards project, and as they have no protection from weather, they will warp owing to getting alternately wet and dry. First, a site on high and well drained ground should be roughly levelled, and completely cleared of brush and even grass and weeds, which must be constantly kept down so that there will be nothing to impede the circulation of air and keep the timber damp. All rubbish, rotting stumps or logs, etc., should be burnt. Boards are then laid for the foundations of the stack a couple of inches apart to give room for air circulation. If stacking softwood, a dry strip of 1 in. by 4 in. is laid crosswise on the boards about $1\frac{1}{2}$ ft. from the back, another strip in the middle, and one $1\frac{1}{2}$ ft. from the front. A layer of the sawn boards, or scantlings, is now laid on the strips, keeping them 1 in. apart, three more strips placed over these and so on till the stack has been built as high as a man can hand up the boards, etc., to a man standing on the top. The cross strips must always be directly above each other or the planks may bend.

For piling hardwood, which has to remain for seasoning for a long time, the same method is used, but the supporting back and front cross pieces should be 8 in. from the ends. When not in use these cross strips should be carefully kept dry.

When the height has been reached, four boards, laid on each other, are placed across the top of the stack at the front, two in the middle, and one at the back. This gives a pitch to the roof, which is now put in place, and consists of boards from front to back, projecting a couple of feet at each end to keep the rain off. These boards are close together and strips are nailed over the cracks to keep the wet out. The roof boards are kept from being blown off by means of ropes across them with weights attached to and hanging down from each end. In a very hot climate brushwood may be laid on the top of the roof boards to protect from the sun.

The seasoning of lumber should, to some extent at least, be undertaken at the mill. Green lumber contains a very large percentage of water, which weighs heavily. If this is evaporated the freight charges on the lumber will be considerably reduced. Thus seasoning means a saving in money to the millowner. The buyer also as a rule prefers to buy seasoned lumber. He is usually established in a town where land is valuable, and he has not the space to stack the lumber properly for the length of time required by natural seasoning, while his work necessitates seasoned wood.

Natural seasoning of large quantities of timber requires an extensive area of land for stacking purposes, the locking up of large capital while it is being seasoned, and heavy fire insurance premiums on the lumber during the long period it is undergoing the process.

Shortly, the object of seasoning is the evaporation of the moisture contained in the wood, and this can be done by artificial means in a brief period without injuring in any way the quality of the timber. Indeed, some timbers, such as those liable to sapstain, are more successfully seasoned in a kiln than naturally.

Evaporation, however, must take place under correct conditions and perfect control to prevent warping, splitting and discolouration. These being attained, the lumber is brought into condition for final working more reliably and satisfactorily than if air dried.

Artificial Seasoning.

There are various makes of artificial seasoning plant. That illustrated here is the Sturtevant process.

There are two methods of seasoning, the " Progressive " and the " Compartment." Under the former the seasoning is carried out in a long tunnel with doors at both ends. The timber to be seasoned is piled on trucks, which are passed through the tunnel on rails. A constant supply of air at the correct temperature and humidity is forced through the tunnel by means of a fan, the flow of air being from the finishing end, that is, against the travel of the trunks. As the air passes through the tunnel it is warmest and driest at the beginning, becoming cooler and more moist as it travels till it reaches the last brought in truck. The truck loads of timber are moved at regular intervals against the

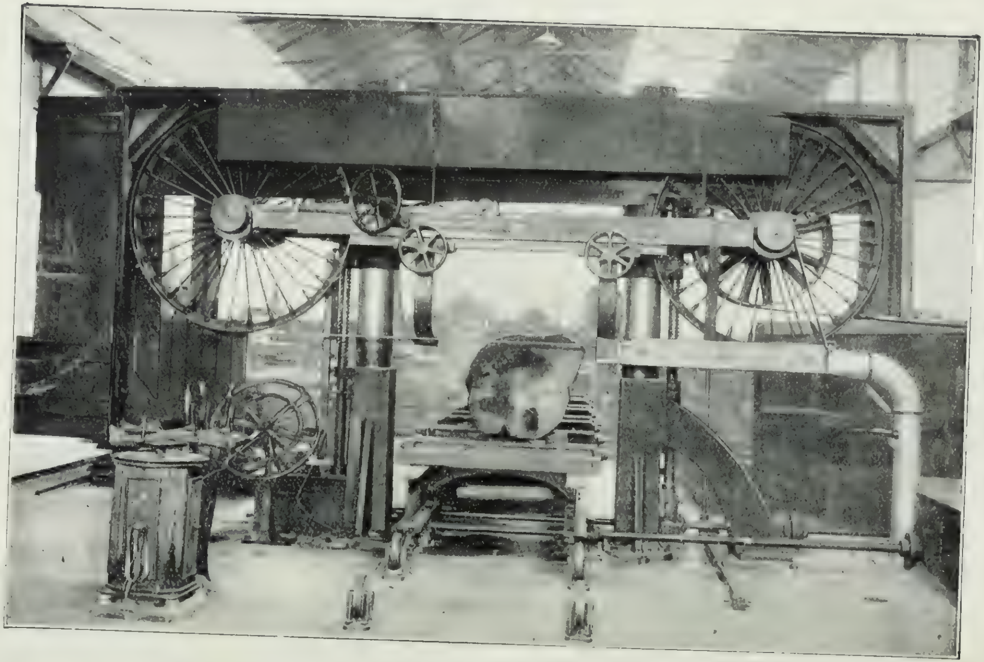

Fig. 133. Log Bandsaw with Sawdust Collector.

[*By courtesy of Sturtevant Engineering Co., Ltd.*]

[*To face p.* 175.

flow of air, meeting drier and warmer air at each move till the load on the first truck is seasoned. It is then passed out, and as all the others are moved up, another truck of green timber is admitted at the further end, and the process continues. Fig. 130 shows the "Progressive" seasoning plant.

The "Progressive" system is not suitable for seasoning frequently varying thicknesses and sizes of timber, and for these the "Compartment" system is used. As the name suggests, the seasoning is carried out in compartments. These are completely closed, and have doors at one or both ends to admit and pass out timber before and after seasoning. The timber is not moved until the seasoning process is completed. In the Sturtevant process the instruments for recording conditions are outside the compartment, which, therefore, does not require to be entered for the purpose of ascertaining these. Fig. 131 shows a compartment open. When the boards are piled in the compartment any end cracks are marked with "X," as shown in the illustration, so that any movement of the timber can be noted.

Permanent Sawmill.

The equipment of a full-sized permanent sawmilling plant comprises a large number of machine tools, depending on the class of work undertaken. The Forest Engineer is hardly likely to be called on to do more than provide the entry ways for the logs and the exits for the sawn lumber, and possibly erect the plant.

In a permanent mill the principal saw for breaking down logs is usually a bandsaw, as illustrated in Fig. 133. It will be noted in the illustration that the sawdust from the cut is not allowed to accumulate, but is trapped at the saw by a sawdust conveyor, by which it is conveyed completely out of the building for storage or destruction. These conveyors for dust, chips, sawdust, and refuse generally can be fitted to other plant, and throughout the building. They not only promote healthier working conditions and a resulting higher output, but they do away with the considerable amount of labour otherwise required for collecting refuse, cleaning up, and so on (Fig. 134).

The refuse from a sawmill is, as far as possible, fed to boilers, which are fitted to burn it, but if these are unable to cope with it all, it should be burnt as collected. Refuse burners for sawmills usually have the tops covered with a metal network to arrest burning sparks. One of these can be seen in the illustration of the sawmill in Fig. 101.

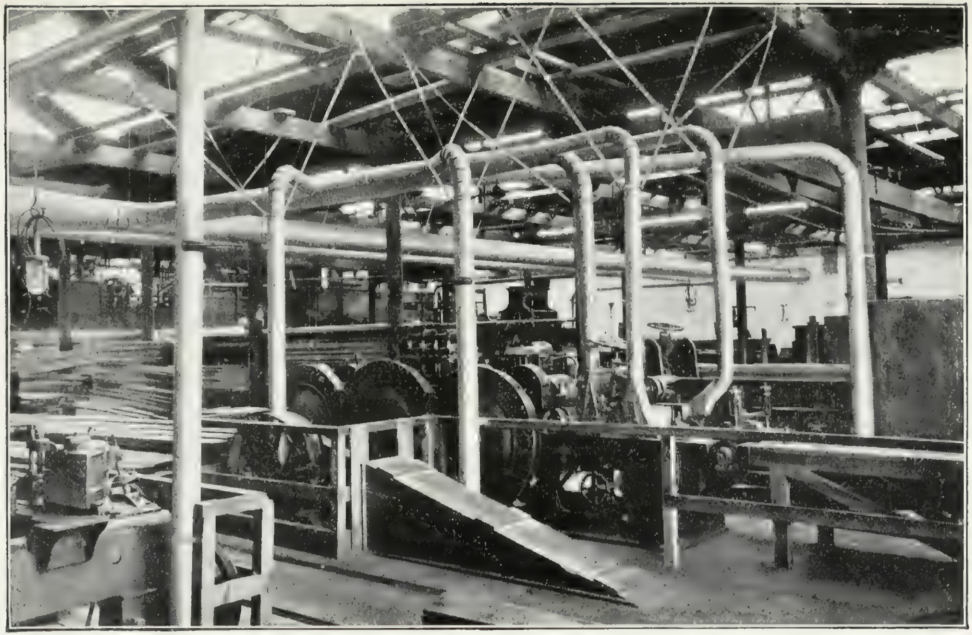

FIG. 134. SAWMILL WITH SAWDUST AND REFUSE COLLECTING PLANT.

[*By courtesy of Sturtevant Engineering Co., Ltd.*]

[*To face p.* 176.

Fig. 135. 2-Ton Caterpillar Dragging Logs, U.S.A.

Fig. 136. Caterpillar Hauling Waggons, U.S.A.

[To face p. 177.

CHAPTER XIV

THE CRAWLER TRACTOR IN FOREST ENGINEERING

A PASSING reference has been made on page 42 to the use of the tractor in hauling. But the crawler tractor is so important an item of plant in forest engineering and forest operations generally, as to deserve a short chapter to itself.

Tractor logging is comparatively new, for it is only within recent years that any tractor has been built which will withstand the very rough usage necessarily entailed in logging operations. There are various makes, but perhaps the best known and most widely used is the "Caterpillar" tractor. It is certainly the best known to the writer, and, as far as he knows, is the original track-laying machine, and is one which has successfully withstood the longest and most severe practical tests. He understands that the tank, which played so great a part in the war, developed from this machine, and what it was capable of in the way of travelling over rough ground, is too well known to require elaboration here.

The Caterpillar is invaluable at any stage of the Forest Officer's work, and it is likely to take the place of animal haulage altogether. It is, for its power, small, light, and handy, and can be turned quickly in any direction, and practically turned round in its own length. In its operation it does not require a degree of skill greater than can be found in any intelligent native in Africa, India, or elsewhere. Its fuel—either petrol or gasoline—is neither heavy nor bulky, but is more easily transported in difficult or out of the way places than any other fuel, or than feed for elephant, horse, mule, or ox. In working, the combustion of its fuel, unlike that of coal or wood, does not entail the risk of forest fires. The use of the tractor does not necessitate the carriage of or access to unlimited water for its working. Hardly any kind of country where men can work is impossible for the Caterpillar. It entails no heavy overhead expense such as is incurred in housing or feeding animals, with the storage of bulky supplies and the provision and payment of attendants.

When it is not working it costs nothing to keep. It is independent of weather, as animals are not. If there is reason for a big push to get out logs, either on account of coming floods or storms, or for climatic or any other reasons, the tractor will work night and day, as animals cannot.

It decreases costs, and allows closer utilisation of timber, and permits the extraction of timber at a profit when it is too small, scattered, or inaccessible for other methods. According to the United States Government Forest Department it does no damage to young growth or seed trees. Climate, altitude, and temperature seem to make no difference to its efficiency.

It is used in the United States Government Forest Service for creating fire breaks, and it has been found that when equipped with a drag or grader it can plough out a fire break 8 feet wide through the heaviest brush and undergrowth, at a cost of from 17s. to £4 per mile. The cost of the older-fashioned methods doing the same work in the same country was from £25 to £100 per mile.

The tractor is the Forest Engineer's friend from first to last. It can penetrate practically anywhere in the forest, and make its own road. It will pull out trees and stumps, and clear the way for road-making. Equipped with a grader it will make the roads, and with a maintainer will keep these roads in good order when not actually logging. While roads for the extraction of timber are generally rough, still, the better they are kept the easier is the hauling over them, and, consequently, larger loads can be hauled more quickly at a smaller cost.

When a forest railroad is to be built, the tractor can go ahead, clear and grade the road, and haul all materials into place. It may possibly take the place of the forest railway entirely, as it can haul heavy loads for long distances on trains of log carriages. It may, in any event, profitably take the place of the spur lines, and allow the main line to

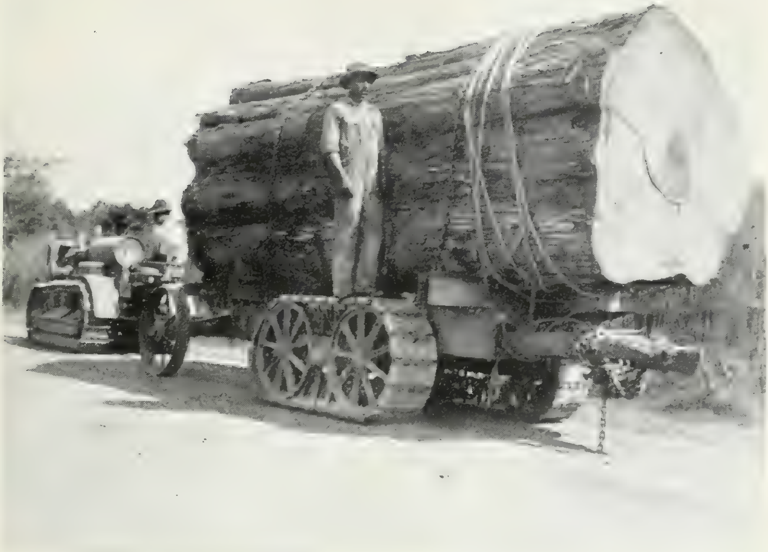

FIG. 137. CATERPILLAR HAULING 1100-YEAR-OLD CYPRESS LOG ON 19 MILE HAUL, U.S.A.

FIG. 138. CATERPILLAR HAULING TURN OF LOGS ON POLE ROAD, U.S.A.

[To face p. 178.

FIG. 139. CATERPILLAR HAULING LOG SLEDS ON SNOW, U.S.A.

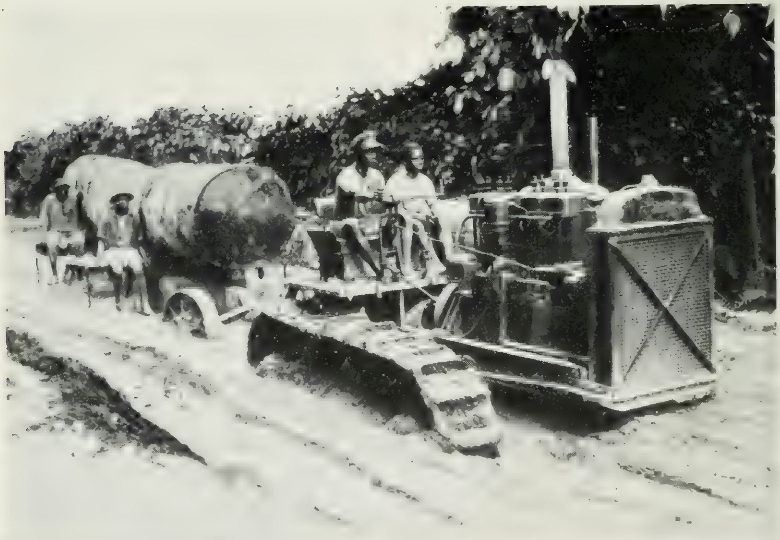

FIG. 140. CATERPILLAR HAULING 17,000 FEET OF MAHOGANY IN WEST AFRICAN MUD.

[*To face p.* 179.

be laid at the lowest possible elevation, owing to the ease with which it can take heavy loads downhill.

It is especially valuable in ground skidding (Fig. 135), but can undertake any department of extraction. As an example of what it can do in this way, it has actually skidded a load of three logs 32 feet long and containing 4,500 superficial feet of lumber, down a 50 per cent. slope 1,400 feet long, the tractor going up over the same road for another load. The average time was 18 minutes per trip, including hooking on and unhooking. It will drag the log from the stump to the skidway. At the skidway, by means of its powerful winch, it will load up a train of log carriages and haul them to river, lake, railway or mill, unloading the timber by means of its own power. Hauling a heavy load of waggons, it will negotiate, apparently with ease, a grade of 25 per cent. on rough, rocky ground (Fig. 136).

With specially built bummers, or tracklaying "dollies," vehicles with an endless track like the Caterpillar's own, it will haul 40 feet length tree loads containing 6,000 superficial feet of timber, at the lowest possible cost for handling and transport (Fig. 137). Hitched to the rear log by an L hook, it will haul a string of 30 logs along a timber slide (Fig. 138). If the pole road previously described is made wide enough to admit the tractor between the poles, it will haul loads of 10,000 superficial feet at good speed against stiff grades, on carriages with concave wheels fitted to the pole rails.

It works equally well on snow (Fig. 139), on rough rocky ground and in deep sticky mud (Fig. 140). When not making roads, loading, or hauling out timber, it will haul in supplies and material. It has never to be laid off on account of great heat or severe weather.

No arbitrary figure can be given as to costs of operating by tractor, as country, climate, local conditions, labour, nature and size of timber, are all important factors, and differ everywhere. But in one instance where animal and donkey engine haulage was replaced by Caterpillars, the cost of timber delivered on the railway was reduced from 24s. to 17s. per 1,000 feet. In another the saving was 8s. per 1,000 feet, while the working crew was reduced by 60 per cent., and the animals done away with altogether.

These are only fairly average examples of the comparative costs of tractor and animal haulage, but they are enough to show that, unless there are special conditions having a contrary effect, the tractor is superior to the animal.

Special jankers or " high wheels," as they are termed, are built for operating with Caterpillars. The width from outside to outside of wheel tire is $11\frac{1}{2}$ feet ; the wheels are 8 feet in diameter with 12-inch tires, and the height from the ground to the under side of the arch is 7 feet. From inside to inside of arch is over 7 feet, so that a log of 6 feet or so in diameter can be carried. The log is elevated to its place by hydraulic pressure through a cylinder mounted on the top of the arch. The elevating capacity is 10 tons (Fig. 141).

Instead of high wheels, logs are sometimes dragged by the tractor, with their forward ends resting on a steel " scoop," or flat pan. The logs are made fast to the tractor by chains attached to the drawbar, and the scoop itself is made fast by an independent chain. When the load arrives at its destination the logs are cast loose, and the tractor draws the scoop out from underneath, and then backs and pushes the logs wherever they are wanted.

Caterpillar tractors are built in several sizes, from the little 2 ton upwards. In one logging operation in difficult, mountainous country, a 2-ton Caterpillar was introduced. It was found to displace at once five men peeling logs to make them skid easier, and five horse teams with the costly transport of bulky hay and other horse feed.

The illustrations in Figs. 142 and 143 show the contrast between the relative spaces occupied by a mule team and a tractor, and the loads drawn by each. Similarly, Figs. 144 and 145 show the contrast between operating by Caterpillar and ox team.

The application of the Caterpillar or crawler type of tractor is possibly the latest method of logging. Enough has been written to show that it is one which deserves the closest attention of Forest Officers and of all engaged in timber

FIG. 141. CATERPILLAR HAULING LOG ON HIGH WHEELS, U.S.A.

[*To face page* 180.

Fig. 142. Mule Team Hauling Log.

Fig. 143. Caterpillar Tractor Hauling Logs.

[*To face next plate.*

FIG. 144. OX TEAM HAULING LOG.

[*To face last plate.*

Fig. 145. Caterpillar Tractor Hauling Logs.

[*To face p.* 181.

exploitation. It is particularly useful in severe climates. In many parts of Africa, for example, which are tropical or sub-tropical, animals do not live. Horse sickness, tsetse fly and other pests rule out economical transport by animals, and make tractor haulage imperative. The tractor of the Caterpillar type will clear the bush, make roads, skid and haul timber, move a mill about and furnish the power for it when set, do general transport and all sorts of odd work (Fig. 146), and, in fact, it is something like the Old British Army, which would go anywhere and do anything.

The photos illustrating this Chapter were kindly supplied by the "Caterpillar" Tractor Company, of San Leandro, California.

CHAPTER XV

FOREST OPERATIONS IN INDIA

No book, or at least no British book, on Forest Engineering would be complete without a special reference to the position of India in forest operations. The Forestry Service in India (including Burma, Assam, etc.) is extensive, old established, and highly organised and efficient. Pioneer work such as is described in earlier pages of this book, and which it must be frankly owned has a great fascination for the writer, will not find much scope in India. There the Forest Officer does not plunge into the unknown, not knowing in what kind of place he will lay his head at night. He will probably lay it in one of the comfortable Rest Houses maintained by the Department. If not, he will have what seems to the writer a luxurious camp and outfit, and an army of servants trained to look after his smallest want, and to provide every comfort. There will be little for him to do that is novel, unless it is to introduce and develop some of the modern methods of extraction indicated in the foregoing pages.

The rough and indiscriminate felling and skidding of trees which has been the rule in Canada and America is not the rule in India. Trees for felling are carefully selected and marked, and must be felled and handled so as to do as little damage as possible to other timber close by. Fig. 147 shows a deodar tree ready for felling which has had the branches lopped off so as to do the least possible damage to the surrounding trees when it falls. Fig. 148 shows the handling of sal logs in the forest—rolling them into place with peavies in readiness for hauling out. Much of the conversion of timber, sawing into sleepers, etc., is still done in

Fig. 146. Caterpillar in Lumber Yard.

To face p. 182.

Fig. 147. Deodar Tree Lopped for Felling: India
[Photo: T. B. Chitrakar.]

Facing next Plate.

FIG. 148. NATIVES ROLLING SAL LOGS: INDIA.
[*Photo: T. B. Chitrakar.*

FIG. 149. NATIVES SAWING WITH FRAME AND DELHI SAW: INDIA.
[*Photo: R. S. Troup.*]

[*Facing last plate.*

FIG. 150. NATIVES HANDSAWING : INDIA.
[*Photo: B. C. Sen Gupta.*]

[*Facing p.* 183

India in the forest by means of handsaws. It is a slow, laborious process in comparison with sawing in the mill, but local custom and the cheapness of labour make it still an existing industry. Figs. 149 and 150 show this hand-sawing.

Even at the present day, extraction is largely carried out by means of elephants and buffaloes, and the writer wishes it to be understood that this is a method in which he is not experienced. It differs from any that have been described. Elephants have always been used in the East in the exploitation of timber, particularly in the handling of teak. They either drag the logs by means of drag chains, as in Figs. 151 and 152, or, if this is more convenient, they push them with their heads, which are protected for the purpose by leather pads. They drag from the breast by means of special harness. They turn logs, when necessary, with their tusks, by which they lever and push the logs downhill, into a river, or down a river when they strand or jam. They are necessarily highly trained, and while they have undoubtedly been of the greatest value in the past, it is difficult to believe that they could not generally be advantageously superseded by some form of mechanical haulage. Possibly conservatism has something to do with their continued use, but the present writer is in no position to dogmatise on the subject.

Instead of the drag chain being passed round the log and caught and tightened up with a hook, as in other places, the custom is to pass the chain through holes cut in one or both ends of a log with axes. This entails considerable waste which would not appear to be unavoidable. If logs have to be dragged down steep slopes the elephant is not harnessed to them. Instead, a bark rope is attached to the log, and the animal pulls by holding the other end in his teeth, as in Fig. 153. If the log runs away the elephant can let go and get into safety, while, if harnessed to it, he would run the chance of being at least seriously injured. The teeth of the elephant take the place of the L hook previously described. This method is wasteful, as elephants used in this way suffer from injuries to and decay of the teeth, and, becoming unable to masticate, fall into poor condition, and possibly die.

At the best, elephants require much care and attention. It is not advisable to work them more than six hours a day, and not advisable to work them every day, especially in hot weather. Their feet must be carefully cleaned after each day's work, and they must be laid off when the least sign of sore feet appears. They must be bathed daily after being allowed to cool down when the day's work is finished. As may be imagined the bulk of food required by a number of elephants at work is enormous, and if this should have to be transported, the cost would be a heavy item. There may at times and in places be local conditions which make the elephant a more efficient and economical extraction agent than any other, but, speaking generally, it would seem that the tractor described in the previous chapter is to be preferred.

Buffaloes are also used, both for skidding logs in the forest and for hauling logs and timber either on bullock wagons or on forest tramways. The method of harnessing these and of loading the timber is shown in Fig. 154.

Even as it is, modern methods of extraction have been introduced to some extent in India, presumably replacing the elephant. High lead ground and overhead skidding are in operation ; the crawler tractor is used with advantage ; wire ropeways and forest tramways are constructed and operated successfully. There can be little doubt that these and other mechanical methods will be largely extended, and where they are unable at present to compete with animal methods, they are likely to be adapted to this end in the near future. Probably the abundance and cheapness of native labour in India have something to do with the disinclination to introduce new methods.

The rivers of India are made use of to some extent in floating timber. In many cases they flow in shallow channels through wide, low-lying, flat plains, which they overflow to a great extent in the flood season, thus making it necessary to devise methods for confining the floating timber to artificial channels. Otherwise heavy loss would result.

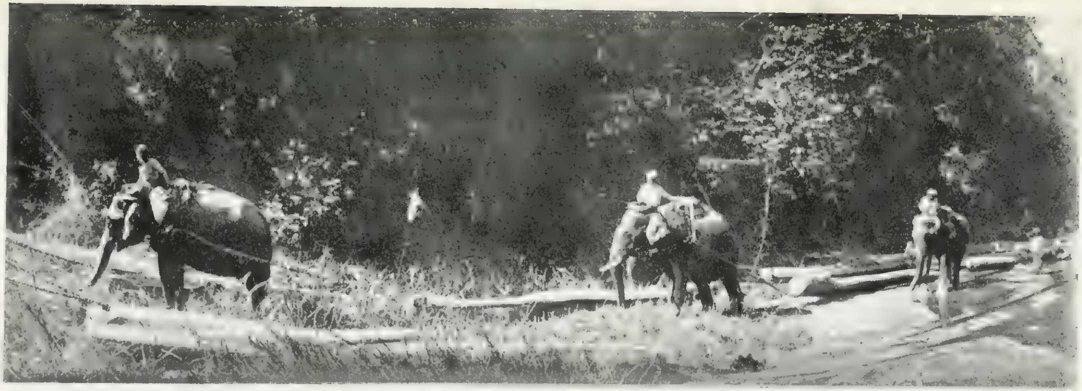

FIG. 151. ELEPHANTS DRAGGING LOGS: INDIA. FIG. 152. ELEPHANTS WORKING LOGS: INDIA.

[*Photo: A. Boyd.*]

Facing p. 184.

Fig. 153. Elephant Dragging by Teeth: India.

Fig. 154. Buffaloes Hauling on Forest Tramway: India.

[*To face next plate.*

FIG. 155. FUEL FLOATING IN HIMALAYAS : INDIA.

[*To face last plate.*

Fig. 156. Rafting Bamboos : India.
[*Photo : R. S. Pearson.*]

[*To face next plate.*

Fig. 157. Forest Rest House on Piles: India.
[*Photo: J. R. P. Gent.*]

Fig. 158. Forest Officer's Bungalow: India.
[*Photo: R. S. Troup.*]

[*To face last plate.*

FIG. 159. WOODEN TRAMWAY AND BRIDGE: INDIA.

[*To face next plate.*

FIG. 160. STRUT BRIDGE : INDIA.
[*Photo : Basti Ram.*]

FIG. 161. SUSPENSION BRIDGE : INDIA.

[*To face last plate.*

Fig. 162. Suspension Bridge: India.

Fig. 163. Fuel Stacked in Depot: India

[To face p. 185.

Fig. 155 illustrates the floating of firewood down the rivers, and Fig. 156 the floating down of bamboo rafts.

The Indian Forest Service is accustomed to something more elaborate in the way of housing than the writer has thought it necessary to describe. However, if the Forest Officer can carry out the building already indicated, he will not be at a loss, and if he has the time and money he can elaborate to his heart's content. Fig. 157 shows a type of Rest House or Bungalow on low piles. It is simple in construction. The piles which carry the weight of the house are carried right up to the eaves, and support the projecting roof as well. The roof is of the kind known as "hipped" and is easily constructed, one beam running up at each corner from the eave to the ridge. A hipped roof is neater in appearance than an ordinary gable roof. All details are clearly seen in the illustration, and this bungalow, or any variation the Forest Officer may prefer, can easily be built if he is able to carry out the instructions contained in an earlier chapter. Fig. 158 is an illustration of another type of bungalow, and is suitable for the Forest Officer's permanent headquarters. Although the writer has "roughed it" and enjoyed the process in every climate of the globe, he thoroughly believes that permanent living quarters, especially in the tropics, should be of good appearance, have every possible comfort, and be entirely suited to local conditions. All this tends to the health, and therefore to the efficiency of the Forest Officer, who should, if he is building for his own permanent use, build to his own idea of comfort, appearance and suitability, and give very careful thought to his design before he begins.

In India, as well as housing, bridges and roads are often of more substantial construction than mere logging requires, although the bridge and tramway shown in Fig. 159 are about as primitive as need be. Fig. 160 is an illustration of a strut bridge of the type described in the chapter dealing with bridges, with the difference that the piers, instead of being of simple cribwork, are of concrete or masonry. This is merely a matter of detail. Local conditions or requirements may make it more desirable to use concrete or masonry, but the bridge shown should present no difficulty.

Fig. 161, while showing the kind of country one may expect to operate in, also shows an example of the suspension bridge, the construction of which has already been described. It will be noted that the log pillars on which the bridge is hung are built in with mason work as well as being sunk in the ground. If this can be done, it all adds to the strength of the structure. Fig. 162 shows a similar suspension bridge in detail.

A very large amount of the woodcutting in India is for fuel, and Fig. 163 shows how this is stacked at the depot.

For the very fine series of photos illustrating this chapter the writer is deeply indebted to the Principal of the Forest Research Institute at Dehra Dun.

In conclusion, the writer ends on the note on which he began. He hopes that this work will be some help, not only to Forestry students whose wishes first inspired him to produce it, but to those engaged in timber exploitation all over the Empire. In a long and unusually wide experience, he does not think he has encountered any problems which are not dealt with in these pages, and if his readers can handle these efficiently, they will be quite capable of dealing with any others necessitated by peculiar local conditions.

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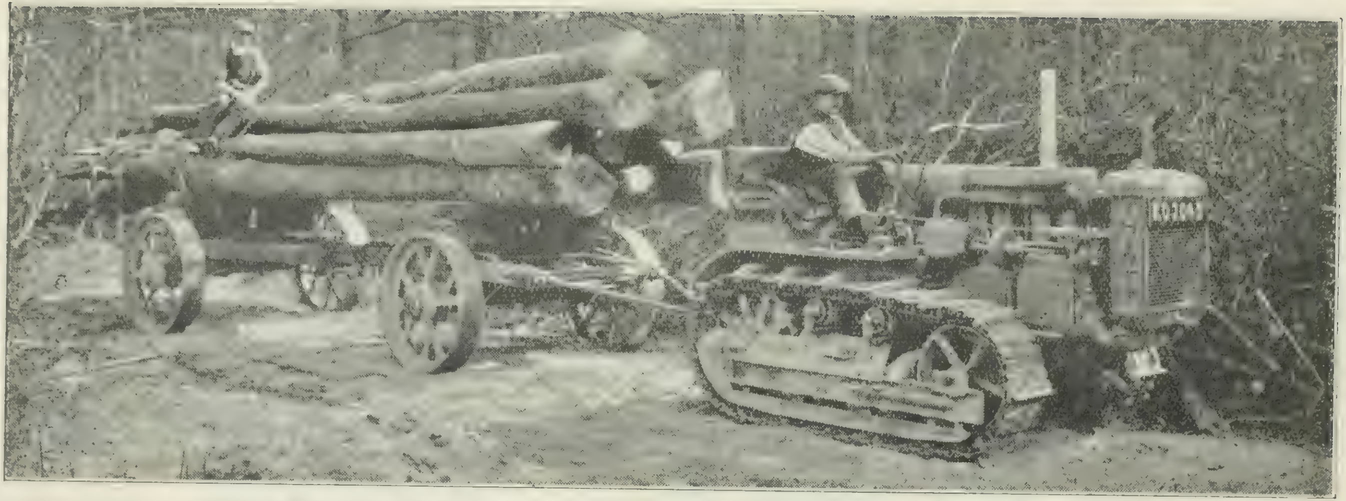

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